MEMOIR

ON

WROUGHT IRON ROOFING,

AS APPLICABLE TO EVERY DESCRIPTION OF BUILDING, AND SHEWING THE MODIFICATION NECESSARY TO ADAPT THE SYSTEMS

TO

EUROPEAN DWELLINGS

IN

INDIA;

TO WHICH IS ADDED

A Supplement, illustrative of the Construction of the five Architectural Sections

OF

CAST IRON BEAMS,

WITH PLATES OF ROOFS ACTUALLY CONSTRUCTED, DETAILS OF THE VARIOUS P

AND

Tables of the Weights of every kind of Iron.

BY

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" There is no part of the art of Building which gives greater scope for the exercise of " genius than that of the construction of a Roof, which shall be entirely appropriate to its specific " object in the situation and under the circumstances in which it is placed, whether it be for " Ornament, Strength, or Stability."—*Barlow's Appendix to 'Tredgold's Carpentry.'*

PREFACE.

PRINCIPLES obtained from opinions, often hastily formed, afford imperfect views of subjects, but maxims drawn from Science can always be analysed and tested, and when applied to the useful Arts, substitute certainty for uncertainty, and security for insecurity, it informs the Engineer how to raise the greatest works with confidence, and how to obtain a maximum of stability with a minimum of material. There is no class of the Arts so directly capable of receiving improvement from the researches of Scientific men as that of Building, nor is there any that in the present day receives so much of their attention. The recent destruction by fire of many of the noblest Public Buildings in England, has called forth the energies of the Engineers and Architects in a most conspicuous manner, and the structures now erecting to supersede those destroyed, shew clearly that Public attention has been directed to repair a fatal error of former ages, by the substitution of incombustible for the perishable material of which the edifices were composed. By the use of frail substances, the Architect is for ever plastering, white-washing and repairing that which, when so plastered and washed is coarse, scienceless, and liable to destruction.

A too rigid economy should not arbitrarily circumscribe construction. The minimum, as regards Buildings, never confirms in application the brilliant theories of calculation—facts resulting from experience merit far greater confidence.

Giving their due weight to those considerations which affect the durability of a structure, the aim should be rather to counteract various tendencies in the cheaper materials, than to make their existence an excuse for adopting the more expensive unnecessarily, while it must not be overlooked that the conservation and repairs, with the tendency to early destruction of the cheaper, may more than counterbalance the original cost of the more expensive but more enduring class of construction

The delineation of noble works actually constructed, and authentic detail of material at present successfully applied and in high repute, should be not only a proof of the great improvements of the times, but a stimulus to similar undertakings, as the surest sources of information and guarantee of equally brilliant issue.

The Tables at the end of the Memoir will not form the least useful portion of it, they have been partly selected from those which formed a section of the Pocket-book of Telford, and partly from Memoranda gathered in the Workshops of Birmingham. Should this little treatise rouse the spirit of enquiry, and aid in any way the development of energy towards the promotion of Scientific knowledge, or the active application of the resources of the country—should it prove of any advantage to the Public Service, or "to the business and affairs of men," the Author will not uselessly have "labored in his vocation."

H. GOODWYN, Captain,
Engineers.

INTRODUCTION.

1. In the introduction of a new system into any department, there are many difficulties which present themselves, rendering caution necessary; and though the path has been rendered clear by the liberal manner in which the Court of Directors have entered into the spirit of improvement generally, and particularly as regards those measures connected with the Department of Public Works, which I had the honor to submit lately to their notice,* yet it is only by a gradually progressive method that the measures can be effectively adopted, and there is a consequent necessity for full and explicit detail connected with the proposed system of Iron Roofing forming the subject of this Memoir, which may at present be considered only as one of several subjects connected with Architectural Engineering, as applicable to the Department of Public Works, which I have in view to arrange, in order to assist, in however humble a manner, towards following as closely as possible in the path, if we cannot keep pace with the increasing strides of the science of the day, and with the hope that our Public Buildings in India may take a higher place in the scale of excellence by being rendered more durable, more elegant, more convenient for the Public Service, and withal more economical; benefits which surely no one can dispute.

2. The advantages resulting from Iron Roofing in England, and particularly the very late improvements in wrought Iron trussing, have been so well acknowledged as to be beyond the hazard of disrepute from mere experiment. It is not many years since the only material employed in the construction of a Roof was Timber, subsequently most of the principal parts were Cast Iron, then followed the introduction of the Wrought Iron as ties, in which cases it seemed to be of little importance whether more Iron was used than was really necessary, which therefore was commonly done, and its actual strength disregarded. Since that time malleable iron has been introduced for more important purposes, being employed to resist enormous strains and bear heavy weights, it is therefore of consequence to ascertain its value; so proportioning the several parts, that whilst perfect safety be ensured, no more material be employed than is necessary.

3. At present many Roofs over large Manufactories, Railway Stations, &c. exhibit the most beautiful combinations of Iron under the two forms of Wrought and Cast; Wrought Iron having nearly superseded the use of Cast for Rafters, Struts and Ties; the latter being confined to Girders, Shoes, Kingheads, Gutters, and occasionally a Strut, as will be shewn hereafter. Wrought Iron trussing is being gradually introduced for the Roofs of the Slips, Shops, and Store-houses of Her Majesty's Dock Yards: the new Public Buildings now in course of erection in London are to be roofed with Iron, and many examples of Iron Roofs, as executed in other buildings, are given in the accompanying plates, with descriptions of the peculiarities of each, and

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* Iron Roofing and Asphaltic Mastic, as applied to Flooring, Roofing, &c.

many other beautiful examples of Cast and Wrought Iron Roofing may be found in the Appendix to [illegible]on of "Tredgold's Carpentry."

[illegible] much [illegible]nce has been attached to this subject, and no inconsiderable talent has [illegible] exerted in [illegible] beautiful arrangement of the material forming many of the subjects.

Mr. Fox, of [illegible]e "London Works" at Birmingham, to whom I am indebted for much valuable information, and who has given his principal attention to the subject herein treated of, has designed, and executed the most elegant and workman-like Roofs in England on these peculiar principles.

4. It is most desirable that stability and economy should characterize the different species of construction, and though on the score of economy, comparison between the first outlay on the present, and Iron principles, cannot be admitted; yet, when the expenses of repairs annually for 20 or 25 years on the present system, together with other attendant inconveniences of leakage and losses be added thereto, the result is in favour of a less destructible mode, and at the end of that time, the Timber Roof remains as liable to annihilation by fire or otherwise, as at first, not so with the Iron Roof, the original cost of which is the only one, and it is indestructible.

5. The peculiar construction of the Wrought Iron Roofs herein advocated, renders them very applicable to Indian buildings, where change of localities and stations are often the result of political and economical measures. they can, from the simplicity of arrangement, be easily taken to pieces, and the parts being light, can be transported by any mode of carriage, and adapted to any other building of the same span. Structures too of increased width and accommodation can by these means be erected, which could not be executed in Timber, except at a very heavy expense, and in proportion as the span increases the Iron Roof becomes more economical than one executed in Timber, effecting besides a saving in masonry, and being infinitely lighter.

The system will besides be found to unite simplicity with durability—certainty will be substituted for uncertainty—security for insecurity; and the largest works, as well as those of less extent, will be executed with confidence: it will be found economical as a whole, from the fact that the union of its parts produces the result of a maximum of strength combined with a minimum of material.

6. The modes of Roofing in the Department of Public Works, [vaulting excepted] have each of them serious defects; of these, some are defects in principle, others in construction; but from whatever cause they may arise, the result is considerable inconvenience to the tenants or loss of property, and very heavy annual expense to the State, while the roof remains destructible. It may be as well then to state a few causes of defect, with a view of applying a remedy.

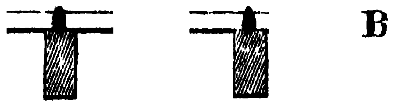
7. For what may be denominated 1st Class Buildings, the Terrace Roof (the nature of which is so well known to the Department as to render description useless) is generally adopted. The seasoning of the timber of which such roof is composed is mostly uncertain, and it is a point of great importance in such heavy structures, not only with reference to its durability, but as affecting the building by the shrinking of some of its parts. Tredgold says, "Two years "after felling is the least time that should be allowed for seasoning; Timber while seasoning "should not be exposed to the sun or wind, and when beams are not to be used the full size

" of the tree, it is better to saw them up after a portion of the period of seasoning has elapsed, " that they may complete the process in that state. Timber is often allowed to be half buried " in the ground among weeds, and it contracts there the seeds of decay before use. Scantlings " of Timber require more attention still, and should be piled up allowing free access of air all " round each piece. Charring Timber is a preservative only to such as is well seasoned; in the " case of unsound, it closes the pores and prevents the escape of moisture. As the process of " drying proceeds very slowly, and quicker in small pieces than large, the necessity for cutting " Scantlings to season some time before use is obvious. Timber may be considered seasoned " when it has lost one-fifth of the weight it had when felled."

8. Timber in an unseasoned state is exposed to more rapid decay from coats of paint, oil or tar stopping up its pores and preventing the escape of inward moisture. Timbers built into newly finished walls often decay, the damp brickwork being an active agent in their destruction, the too hasty plastering of walls, by keeping in the moisture, is an additional means of hastening the effect.

Sometimes the external parts of the Timber alone are seasoned when the beam will soon be found to be in a state of decay internally: alternate dryness and moisture from leakage is another cause of decay, and the more to be feared as the ends of the beams in flat roofs, lying under the parapets, cannot be protected by periodical coats of paint.

9. The mode of laying the burgahs is the weakest possible from their short lengths; each piece being separately subject to strain which may not affect all equally. The following extract, from the latest edition of Tredgold, on the subject will prove the above assertion.



" When a long Timber A B is laid over several points of support, the strength of the intermediate " parts is nearly doubled, or twice as much as when the Timber is cut into short lengths, " —Hence the importance of extending purlins over several trusses, rafters over several purlins, " contriving so that the joinings shall not be opposite to each other."

10. A practice used to be in existence of forcing or cutting a beam to a certain degree of camber, under the idea that it partook in that form of the nature of an arch, this is a fallacy which should be expelled, as when such cambered beam settles, its tendency is to thrust out the walls instead of being a bind to tie them together, and there is no necessity for making walls of an extra thickness to resist that thrust.

11. Sufficient attention is not given to the terrace itself in its component parts, quantity being too often substituted for quality, and a judicious selection of the lime not always made nor the proper proportions of cement and burned clay so as to form the most compact mass, which should possess hydraulic properties.* The proper drainage of rain water from the roof is almost

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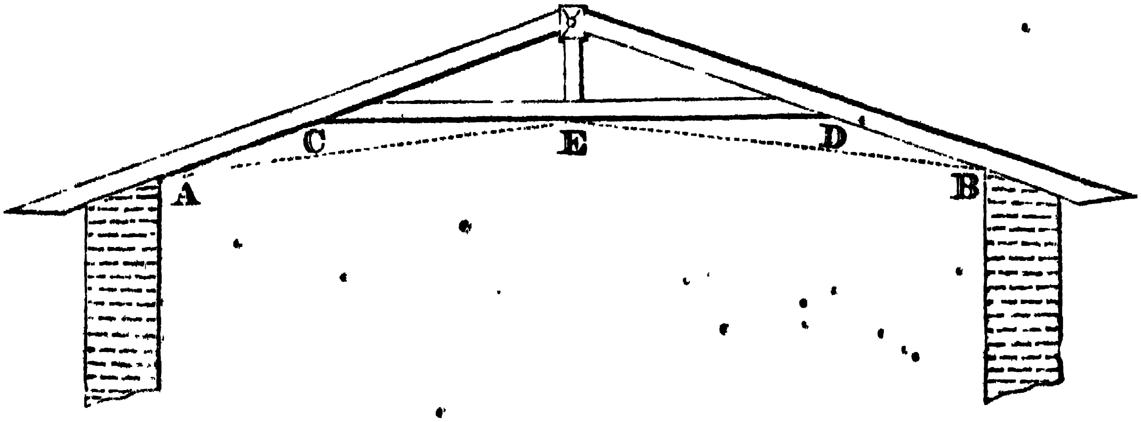
* I use the expression "burned clay" because the bricks from which Soorkey is made are not always most proper for the purpose, often containing too much sand, and perhaps too much or too little burned, though greater care is necessary in the composition. An Article on Cements and Mortars is in contemplation to be put forth with other subjects connected with the Department of Public Works.

entirely overlooked, it being allowed to fall either in streams from ugly projecting drain tiles inserted under the cornice to the disfigurement of the base of the building, and annoyance of passers by, or, in the absence of drain tiles, to trickle down the sides of the buildings, leaving a slimy evidence of its course—Art. 108.

The whole roof, with its mass of terrace-work often disadvantageously raised in the centre to form a slope for the water, produces an inordinate load on the walls, while the insidious white ant is invisibly scooping out the solidity of the timber and affecting its safety.

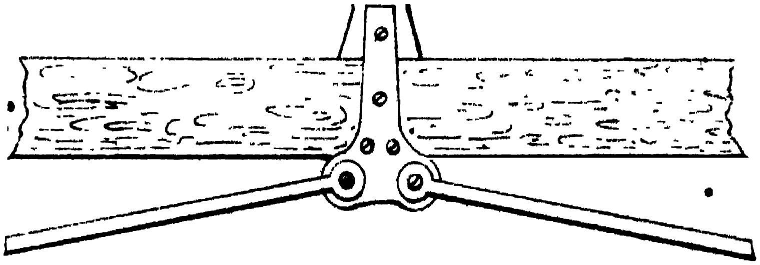
12. The tiles or bricks used in the covering are not always laid in hydraulic mortar, thereby increasing the causes of leakage. Mr. Fowler, a Fellow of the Institution of British Architects, whose practice in flat roofing has been great, has given a short treatise in the Transactions of that Society on the subject. Having failed with Timber and the ordinary mode of terracing, he resorted to Cast Iron Girders and tiles laid in *cement*, and though the Girders were three feet apart, the tiles had no intermediate support (save a temporary one, till the cement settled) and he says, speaking of this roof, " Experience in this case is important as it exposes the contingencies to " which this mode of (flat) covering is liable, and in what manner they may be remedied or " prevented; it serves to shew the necessity for providing a very stable construction for the " reception of a terrace: timber therefore, from its extreme tendency to shrink, is inadmissible."

13. The Tiled Roof is the next in value, and used for buildings of the 2d Class. This would be an excellent mode of covering if the method of securing the tiles were improved on, and by all that can be gathered from the best examples of Carpentry, the framing of a roof, as generally practiced in India, is not on the most judicious or economical plan. It is true that one of the original reasons for the introduction of the Tie-beam to a Truss was to reduce the walls to a minimum thickness by taking away all lateral thrust; but as its great use is to prevent the spreading of rafters at the foot and consequent disarrangement of the roof, its presence is most necessary. The most common construction of our trusses is by means of the Collar beam,[*] the weakness of which will be shewn by the following diagram.



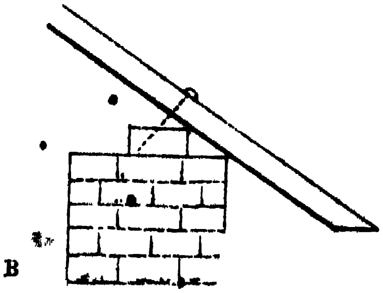
[*] This remark is principally applicable to the Divisions in Upper India. In Calcutta are to be seen some good specimens of Trussing, which doubtless will (if the white ant will permit them) remain examples of superior workmanship; and I have no doubt that there are others.

C D represents the Collar beam of a Roof, the whole weight of which Roof is sustained by the parts of the Rafters C A and D B, and the Roof will settle in proportion to the weight of the covering by the deflection of the lower parts of the Rafters C A and D B—partial spreading of the feet of the Rafters cannot be prevented by this construction. Changes of form in an assemblage or system of framing almost always increase the effect of the weight and produce cross strains which may be attended with the worst consequences when such changes are not foreseen and provided for. A remedy for the spreading of the feet of the Rafters in such construction may be applied in the shape of light Wrought Iron Rods as ties, shewn by the dotted lines A E, B E, secured to the centre of the Collar beam by a double eye bolt, forged with spreading jaws at the lower ends,



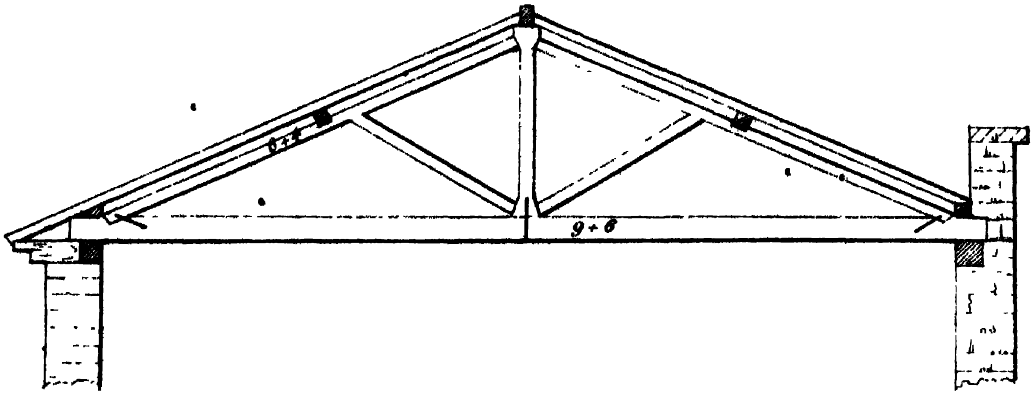
to embrace the feet of the Rafters, being secured to them by a key.

14. This plan is more applicable where height in the centre is an object, in other cases an iron tie rod, horizontal from A to B, will be found an easy, efficient and economical addition to such a truss, and in great spans the king-post may be lengthened by a rod from the point E, to support the horizontal tie. Buildings as at present constructed are not of such great span, but that a tie beam of moderate scantling (properly supported by a King, or in larger spans by two Queen posts) may be advantageously employed. How often are not the proper joints of the parts of a framing neglected, and but a partial connection of rafter and strut or tie made? the greater part of the weight or strains being left to be borne by an iron pin; the feet of the rafters are, in like manner, nailed to the external edge of the wall plates, instead of being notched on to them.



Iron Pin nearly in the direction
of force exerted to draw it

The annexed is a truss in common use in England, and in accordance with the rules of Carpentry for spans from 20 to 30 feet, the scantling of the rafter of which is from 5″ × 3″ to 6″ × 4″ according to the span, and for a covering of slates, zinc or tiles, placed from 7 to 9 feet apart.



This scantling is not more than is given to our trusses for a less span but with additional parts, and placed at a distance of five feet apart,—a reduction in the number of trusses, properly framed, with intermediate small rafters of light scantling on the purlins, is an economy of material.

15. Nothing is more perishable than the bamboo frame placed on roofs, the Weevil and rot soon destroy it, while the tiles laid on with a most unnecessary load of clay bring nests of white ants in direct contact with the frail material; the sinking of the tiles, and considerable leakage is the consequence, and annual repair or renewal a constant and heavy expense.

16. Tiles of a better description might be laid on battens in a way similar to an improved mode of slating in England, which prevents the action of the wind whether on an open shed or externally on a closed building, and will afford a more secure and permanent covering.*

17. The still more perishable nature of thatched roofing needs no comment, and though cool they are a constant source of dirt and expense—the remarks in the mode of trussing are equally applicable to this species of roofing.

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* The introduction of a better description of tiles and more secure mode of tiling is in contemplation, of which an account will be found herein.

WROUGHT IRON ROOFING.

18. In comparison with the above, the following details of a system of light Wrought Iron Roofing will display advantages enumerated in the Introduction to this Memoir, and which have attracted the attention of the Government and Citizens in England for prevention of the disastrous effects of fires, which of late years have committed such fearful ravages on public and private property.

It was stated in the Introduction that the adoption of Wrought Iron framing was gradual (Art. 3), having succeeded the Cast Iron roofs by successive stages, from the simple tie rod to the perfection of the beautiful arrangement of which this Memoir professes to treat.

19. As the following pages relate to the different purposes to which iron is applied in roofing, it may be useful to state the properties of the metal under its two forms of Cast and Wrought.

20. The reduction of iron ore is by means of a furnace in which alternate layers of the ore, limestone, (which acts as a flux) and fuel, are placed, it is urged by a powerful bellows. The Iron is thus deprived of its oxygen: in this state however it is very brittle, and too hard for tools to work on it. Coal, as it generally contains sulphur, is unfit for the reduction of the ore, charcoal is the best fuel, and next to it coke.* The Crude Iron obtained as above, is melted in close mixture with its fuel, the air being almost shut out, it thus absorbs carbon, and is thence run into pigs, by channels made in the sand close to the furnace.

21. The weight of a casting should be computed before hand, that it may not be spoiled for lack of material. The weight of metal may be approximated to by the weight of the pattern of wood, which, if of deal, multiply by 14·4, and if mahogany, or any similarly heavy wood, by 10·8, for the weight of the casting.

Particular care should be taken by the Engineer requiring a casting, to have a pattern made and fitted to his work for which it is wanted, and to make the necessary preparations of hollows, holes or cavities, as Cast Iron is so difficult to work on after it is received from the Foundry. Holes are exactly the reverse in patterns, being convex projections of the size of the apertures, which in the moulds contain a Core. Glue should be avoided in making a pattern, as it melts, small nails are best for fixing projections. Allowance must also be made for contraction of metal in forming the pattern, somewhat less than 1-8th of an inch to each foot of extension, will be a guide for the best Pig Iron.

22. *Cast Iron* is a very valuable building material owing to its strength, hardness and durability, and the ease with which it is moulded. There are two varieties; the gray and white, the former softer than the latter, slightly malleable in a cold state, and the surface of a fracture of a granular structure, with a lustre resembling small particles of lead strewed over the surface. The white variety is very hard and brittle, the fracture presenting a chrystalline structure of vitreous lustre, like the reflection of light from a combination of small chrystals. The gray is therefore most suitable where strength is necessary, and the white where hardness is the principal

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* Coke is coal burnt with free access of air till it gives no smoke, it is then shut up from contact with air, and further combustion prevented. It may be burnt in open heaps, and when brought to a red heat, covered with clay to exclude the air, and watered through the clay to harden it.

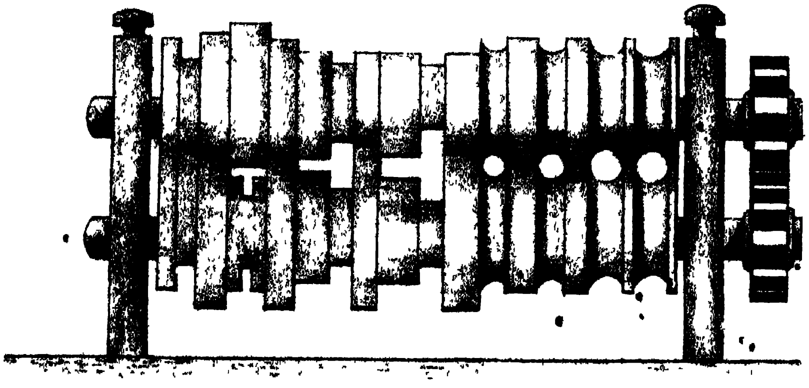
requisite, the color and lustre being the chief indications of the quality of the iron; that of a uniform gray color of high metallic lustre being the best and strongest; such iron too will bear on its edge a slight indentation from a smart blow with a hammer without appearance of fracture, which iron of an inferior quality will not. The resistance of gray iron to rupture, from the force of extension, does not exceed 20,000 lbs. on the square inch, but its resistance to compression is great—being computed from experiment at from 90,000 to 120,000 lbs. on the square inch.

23. Iron for malleable purpose, after having been reduced from the ore to a crude state by the first process before mentioned, is remelted in a reverbatory furnace, or one that has a current of air acting on the Iron, and subjects the Iron to the heat of the fuel, without being in contact; when fused, it is stirred about by Iron rods, which is called " puddling," when the Iron becomes tenacious, like dough, having parted with its Carbonaceous matter, it is withdrawn and receives several blows from a ponderous hammer, worked by machinery, which renders it compact and drives off the Oxide which may have formed during the "Puddling." The bars thus formed are carried to the Rolling Mills, whilst in a glowing heat, to be formed into the required dimensions.

24. Bars that are rolled should be first reduced to a smaller size than required, then cut and doubled, brought to a welding heat and passed again through the rollers to their proper size.

25. Rods to resist great strain, should be " faggotted," i. e., several rods welded together to form one of the dimensions wanted: nuts requiring strength should always be formed by doubling or tripling the pieces and incorporating the mass at a welding heat: great care is necessary in faggotting to make good joints, the Iron should be brought to a sufficient heat and the Oxide prevented from forming by sprinkling a little dry sand on it in that state, which forms a coat of glass that is driven off by the first blows of the hammer in welding.

26. A pair of Rolling Mills is shewn below for rolling T and Rod Iron, the metal in a glowing state is passed through the larger aperture first, then re-passed through the next, till it attains its proper dimension in the smallest. The Cog wheels on the axes of the rollers are connected with the moving power.



27. Wrought Iron may be tested as to quality, viz. by color, lustre and texture of a recent fracture, that submitted to examination should be in bars at least one inch square, or if flat, at least ½ inch thick, as the texture of smaller bars will differ much owing to the greater elongation of the fibres. The surface of a recent fracture of good iron presents a clear gray color of high metallic lustre, and the grains present an elongated appearance slightly crooked at the ends, giving an idea of force having been exerted to produce fracture.

The fibrous texture is an inherent quality of good iron, that which does not possess it is of inferior quality and will not answer where great strength is necessary, such varieties will be found to shew a fracture of a deep leaden color.

28. The strength of Wrought Iron is variable, depending not only on the natural qualities of the metal, but on the care taken in forging, and the greater or less compression of its fibres when drawn into bars of different sizes.

29. The resistance offered by the best Wrought Iron to rupture by the force of extension is on an average 56,000 lbs. per square inch, for bars whose cross section is greater than one inch; and it has been found by comparison of relative strength of bars of different sizes, small bars are the strongest. The resistance of Wrought Iron to a compressive force has not been estimated as it is never used for vertical supports—the Cast Iron being in such cases superior.

30. The best Cast Iron used in England is denominated "Cold Blast, No. 1 Pig," and is run from a Cupola furnace. That for the Wrought Iron work is of the kind called "Best Merchant."

31. Thin Iron Plates are liable to decay from rust in damp situations, and when once rusted the decay goes on progressively under any paint that may be put on; to prevent this, therefore, the Iron should be heated to almost a blue heat, and then immediately struck over the surface with raw linseed oil, or wax, by this method the pores are filled, and the Iron acquires a uniform coating as if varnished. Smeaton generally observed this mode.

32. Amongst the late examples of Cast Iron Roofing are two constructed by Messrs. Maudslay and Field, at Lambeth, one over their manufactory, where a Wrought Iron Roof would not have answered, as pulleys for heavy weights in the working of the Establishment are often attached to the Roof Girders, which the tie rod of an entire Wrought Iron Roof would not bear. The ribs are in three separate castings, bolted to hollow Cast Iron Standards, on the prolongation of which are light columns supporting a sky light, which is roofed by means of light Cast Girders; the whole is crossed by rectangular battens of Iron, and slated. The ribs are six feet apart, the span of the roof 54′ 3″.

33. The other is over the Falcon Glass Works, its span is 50 feet, the construction of the Cast Iron Ribs somewhat similar to the former, in addition to which is the introduction of a Wrought Iron horizontal tie Rod adjusted and secured to the centre of the Girders.

34. Cast Iron subsequently assumed another form, and was used in conjunction with Wrought Iron, as is shewn in Pl. XLIV. of Tredgold's Carpentry (new Edition), a roof over the Smithery of the Butterly Iron Works, the span is 40 feet, and it is 150 feet long; the building is very lofty; here no weights are required to be attached to the tie rods; Cast Iron has been employed for the rafters, struts, and for the parts acting on the thrust, and the Wrought Iron

used for those subject to tension. The section of the Cast Iron is given in the plate referred to. The frames are placed 15 feet apart, but still the construction, though extremely good and not very expensive, is more heavy and unwieldy than an entire Wrought Iron Roof, as will be presently shewn, though the introduction of rafters and struts of Wrought Iron, giving the greatest strength with a minimum section of material, appears to have been gradual. Experiments were made to ascertain the value of Bar Iron for those parts of the roof subject to thrust, and these being satisfactory, several roofs on Railway stations were thus constructed.

35. (Pl. 1.) of an Engine House on the Great Western Railway, at Reading, is an example of one of these, but a glance at this in comparison with a roof, such as is shewn in (Pl. 2, Fig. 2) for a roof of equal span, will shew how very much more metal had been expended on the former than on the latter, how far the value of the Wrought Iron was in this early stage of its application underrated, and (by a slight anticipation of the subject,) how great an advantage has been since derived from the rolling of the Iron into the section of that in (Fig. 2,) or the ⊤ form being that where the least quantity of metal gives the required stability. Vide Pl. 4, Section No. 6, (Art. 40.)

36. The sectional area of the Reading Shed Roof rafter is $4'' \times 1'' = 4''$, and that of the ⊤ Iron Rafter in Pl. 2, Fig. 1, is $\overset{\text{Web.}}{\overline{2\tfrac{1}{4}'' \times \tfrac{3}{8}''}} + \overset{\text{Table.}}{\overline{2\tfrac{1}{2}'' \times \tfrac{1}{4}''}} = {}''1{\cdot}468$ and for a Roof, such as is given in (Pl. 5 of 60 feet span, the sectional area of the ⊤ Rafter is $\overset{\text{Web.}}{\overline{3\tfrac{1}{3}'' \times \tfrac{1}{2}''}} + \overset{\text{Table.}}{\overline{3'' \times \tfrac{3}{8}''}} = {}''2{\cdot}790$, giving a result of considerable superiority both in actual weight, and consequent cost of material. The difference between the solid contents of struts is in the same ratio.

37. The mode of fitting the parts and of adjustment of the Reading Roof is heavy and unscientific. The trusses have besides been placed at the unnecessarily small distance of 4′ 9″ from centre to centre.

38. (Pl. 2. Fig. 1.) of a Roof over the "Cowlairs" Station of the Glasgow Railway, one of the early erections of Mr. Fox of Birmingham, is another example of the Flat Bar Iron Rafter, the breadth of which is 3″ though infinitely lighter than the last, and the construction on the whole of a novel and not inelegant design, it has, independant of the Rafters, defects which will be noticed hereafter: the span of this Roof is 32 feet.

39. It has been generally admitted that Bars of Malleable Iron, beyond a certain weight, cannot be so well or cheaply manufactured as those of less dimensions, and it is no less certain, that by a proper disposition of the metal in the Sectional area of the bar, a greater strength may be obtained with a given weight than with a greater weight injudiciously disposed. It was most likely under these impressions, (the Iron Work remaining still heavy and expensive) that Mr. Fox, after many experiments, was induced to attempt the manufacture of Iron of a ⊤ Section* as possessing the property of sufficient strength with economy of metal. The proprietors of the Rolling Mills at Birmingham were applied to, who after many failures, arising from difficulties experienced in the adjustment of Rollers for the purpose, succeeded in producing Iron of such a satisfactory form as has been since generally adopted in the various Wrought Iron Roofs of which this Memoir treats.

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* I am not aware of any other Engineer or Mechanist having adopted this form of roof, though from the many advantages it possesses, it must come into general use; the demand is now very great, and at the last visit I paid to the manufactory of Mr. Fox, he had 7 ACRES of this kind of Roofing in hand!

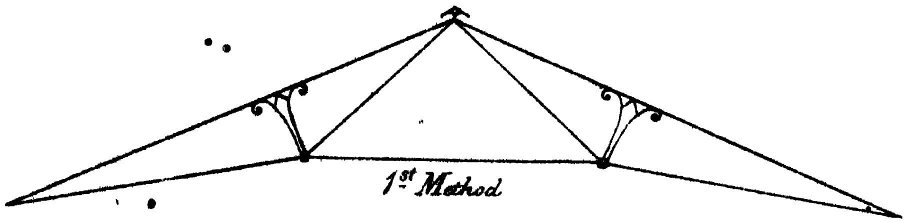
40. The ⊤ Iron is applicable to both rafters and struts, the Sections differing according to the spans of the spaces to be covered. The following table having reference to (Pl. 4,) will shew the varieties in full size for different purposes.

No.	Span of Roof.	Web.		Table.		Weight per foot of length.	Remarks.
		Length.	Thickness.	Length.	Thickness.		
1	60 feet, …………	3⅛″	½″	3″	⅜″	Not weighed.	
2	50 ………………	2¾″	⅜″	3″	¼″	6 lbs.	
3	40 ………………	2¼″	⅜″	2½″	¼″	5 „ ……	The Rafter of Pl. 2, Fig. 2, is 2⅛″ only, in the Web × ⅜″, and considered the minimum for that Span.
4	Strut for 40 feet Span,…	1¾″	⅜″	2″	¼″	3¾″ „ ……	Will answer for 3d or small Strut of 60 feet Span.
5	Rafter for 20 or 25 feet Span, ……	2¾″	½″	2¾	⅜″	Not weighed,	May be used as Principal Strut for 60 feet Span.
6	35 to 40 ………	2⅛	⅜″	2½	¼″	……………	Rafter, 40 feet Span on 1st system.

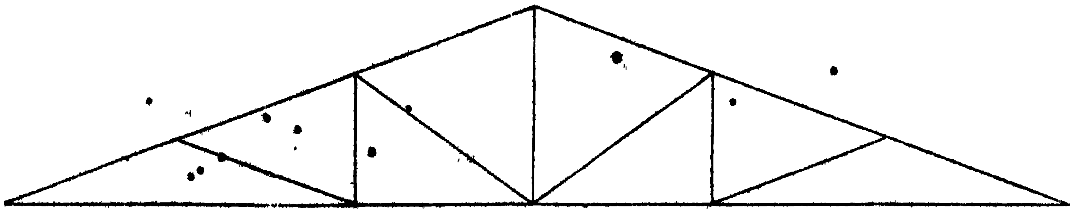
The junction of the web and table is rolled rather thicker than the other parts, avoiding the angles by a curve on each side, that being the point most liable to fracture from the necessity that exists of laying the ⊤ Iron with the table upwards, in order to rivet the angle irons or battens to it, and for proper connection of struts, otherwise the position of the table downwards is the strongest.

41. Two modes of applying the ⊤ Iron are now adopted, which have received from time to time various improvements, till sufficient strength has been obtained with the least possible material which will be noticed in due course.

The two kinds of Roofing are shewn in skeleton outline annexed;



1st Method



2nd Method

and as we shall have occasion to refer to them, they are designated "1st and 2d Methods."

42. THE FIRST METHOD

is more particularly adapted for Roofs of moderate span, and should not be applied when that exceeds 40 feet. (Pl. 2, Figs 1, 2,) are illustrative of this method (and in order to shew the gradual perfection of this construction, we will compare the Roof of (Fig. 1) with that of Fig. 2) the former, as before stated, one of the first erected, and the latter containing the latest improvements, and beyond which state of excellence it is scarcely possible to carry it, combining as it does the valuable properties of simplicity, elegance, durability and economy.

43. The first method is composed of two inverted trusses abutting against each other at the ridge, and tied together by a horizontal rod, the parts are a combination of Wrought and Cast Iron, viz.

WROUGHT IRON 2 Rafters of ⊤ Section,... rolled.
2 bent Tension Rods, ... rolled.
1 Tie Rod,.................. rolled.
CAST IRON...... 2 Struts.
1 King-head.
2 Shoes.
1 Ridge Cap.

44. THE RAFTERS

have already been described (Art. 40,) the Section for 40 feet span being No. 6 in the table and No. 6 Section, Pl. 4. The upper ends of the Rafters are let into the Cast Iron King-head and secured thereto by two bolts and nuts. Fig. 1, Pl. 9.

45. THE KING-HEAD

in (Pl. 2, Fig. 1,) is shewn to be very contracted, the ends of the Rafters are by this means brought within 3 inches of each other, and the ends of the Tension Rods quite close, causing difficulty in the adjustment of the screws after the Truss is put together—one of the improvements as shewn in (Fig. 2,) is the expansion of this King-head, giving a bearing of 8 inches between the Rafters, and a more convenient interval between the ends of the Tension Rods, Screws, and Nuts. This form too is far more graceful. The King-head is accurately fitted to receive the Ridge-cap, and the bolt which screws it is $\frac{5}{8}''$ diameter. (Vide Fig. 1, Pl. 9.)

STRUTS.

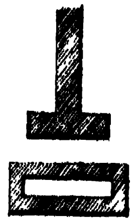
46. In the centre of their length the Rafters are supported by Cast Iron Struts, and these form prominent points in the superior merits displayed in the latest constructed of the two roofs under comparison. In (Pl. 2, Fig. 1,) the Strut affords but a short bearing of 8" for the support of the Rafter, but mark the difference in the roof (Fig. 2,) the upper part of the Strut is expanded, forming three points of rest for the Rafter, the outer ones being two feet apart, by which greater stiffness is given to the construction and may be noticed in comparison with the 2d method for small spans, as an advantage in giving the Rafter a firmer support than the single connexion of the other. Figs. 1, 2, of Pl. 9, shew a Strut one-third full size. The Rafter is secured to the three sockets in the upper ends of the Strut by $\frac{1}{2}''$ bolts and keys,

the lower end is formed into a jaw for the reception of both Tie and Tension Rods, through which is a ⅞″ bolt, secured either by screw and nut or by a key.

47. When there is no skylight to this Roof the points of support should be rather below the middle of the Rafter, as the connexion at the lower ends of the Struts is stiffer than at the Shoes, the weight of the skylight acting as compensation.

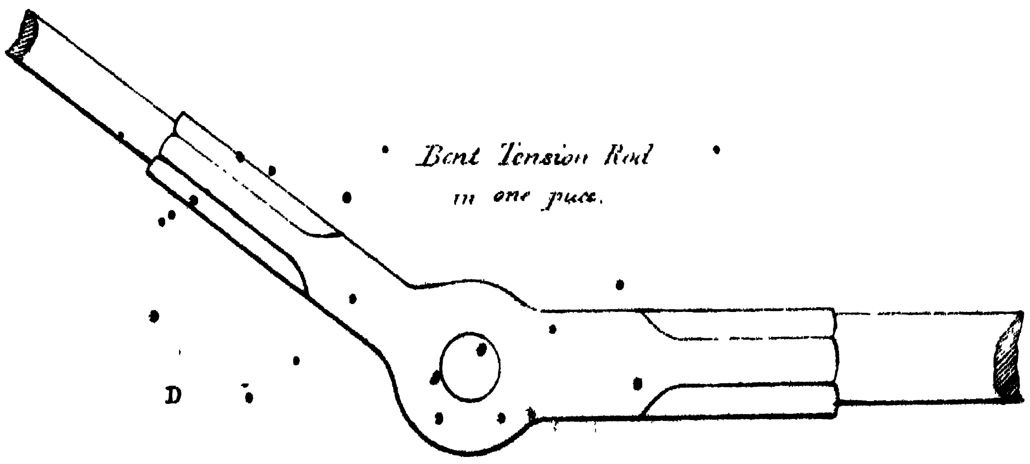
48. THE SHOES,

which are of Cast Iron, are prepared to receive the ends of the Rafter and Tension Rods —these latter are not however always secured to the Shoes; (Pl. 2, Fig. 2,) shews the Rafters fitted to the Shoes, and the Tension Rods secured to the Rafters, both by means of bolts and nuts; the Shoe has a return for receiving a holding-down bolt ⅝″ diameter and 5 feet long—this is necessary in large open sheds or buildings in exposed situations; the end of the bolt is oblong, square-headed, which is dropped through a nut previously built in the wall, and a half turn of the bolt secures it. The hole in the return of the Shoe should be slightly elliptical, to allow of the holding-down bolt having a little play. The securing of the Shoe in this way is not always necessary, many of the examples shew it merely laid on the wall plate, the whole system of connexion being so firm as to cause no apprehension of derangement. This mode of fastening the Tension Rods too is adopted when the ends of the Rafters are made fast to cantilevers, or cross girders, which is done by sockets being cast on the girders for their reception. In (Figs. 3, 8, 9, Pl. 9,) is shewn a mode of securing the ends of the Tension Rods to the Shoes below the Rafters by means of screws cut at the ends of the rods and nuts, this admits of a very nice adjustment of the parts of the Roof, and is applicable to either system.



49. THE TENSION RODS

of rolled Iron are forged, each in one piece, to the angle necessary for their correct adjustment at the three points of connexion with the King-head, Struts, and Shoes. The lower half of each Rod is of greater substance than the upper, having not only its duty to perform in bearing the Tension from the King-head, in the direction of its length, as part of the inverted Truss, but also that of a Tie in a nearly horizontal direction; thus the Tension Rod (Pl. 2, Fig. 2,) of the 40 feet Span Roof, is 1″ diameter between the Strut and Shoe, and only ⅝″ between the King-head and Strut.



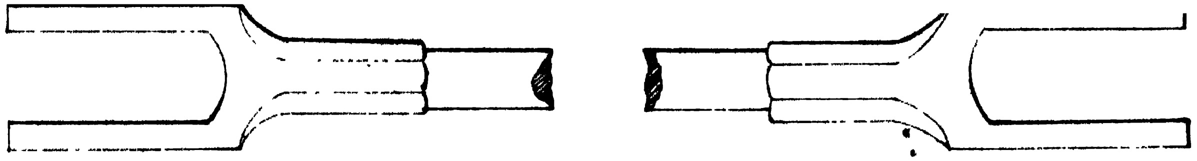
Bent Tension Rod in one piece.

50. The screwed ends of the Tension Rods should be of such diameter that the Sectional area of the bottom of the threads shall not be less than that of the other part of the Rods. This rule is also applicable to screws cut at the ends of any Rod submitted to Tension, as it preserves an equal solidity of metal throughout the whole length.

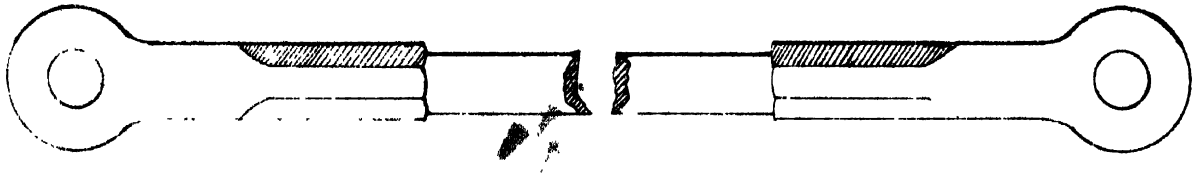
51.

THE TIE ROD,

which completes the arrangement of the Truss, is of a medium substance between the two ends of the Tension Rods; that in the example under examination, for a 40 feet span is ¾″. The ends are formed so as to embrace the angle of the Tension Rods, which connexion is secured to the jaws in the lower ends of the Struts by ⅝″ bolt. The line of Tie in this, as in the other method, is not horizontal, though that position is theoretically proved to be the strongest (vide calculation at the end of this Memoir) the strains being less, but were the Tie-rod thus placed, the longer and heavier must be the Struts and Suspension Rods, so a true principle of economy has directed a medium to be preserved, combining lightness with a proper regard to sufficiency of strength.



Central Tie Rod



52. If any the slightest doubt should arise regarding the strength of the Rods, they should be subjected to a direct strain of not less than 8 Tons* per square inch.

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* The Weights of Cast and Wrought of different kinds will be found in Tables at the end of the Memoir.

53. RIDGE CAP.

(A Pl. 2, Fig. 2) of Cast Iron, is bolted to the top of the King-head securing the Ridge Pieces, shewn in Section above it; which are also of Cast Iron, and of a length corresponding with the distance between the Centres of Principals, these are cast with a slight lap on the under edge to allow the tiles or slates to lie well under them preventing the possibility of leakage. Fig. 4, Pl. 9.

54. THE SECOND METHOD

differs principally from the first in supporting the Horizontal Tie by means of King and Queen Rods, and in the Struts being of Wrought ⊤ Iron, it may be applied to spans of considerable extent.

55. In a competition for a Roof to be thrown over an Octagonal Engine Shed on the Birmingham and Manchester Railway, a design for a Wrought Iron Roof by Mr. Fox on a principle similar to this, but somewhat extended, and with extra Radiating Ties, was considerably under other Estimates submitted, all of which were for Timber. The diameter of the shed being 130 feet. The advocates for Timber were of course obliged to have recourse to intermediate supports, or 8 columns within the Walls, whilst the design for the Wrought Iron Roof was to Span the entire space, and nothing but the most unnecessary fear on the part of some of the proprietors (unscientific men) prevented this splendid design from being carried out.

56. (Pl. 5, Fig 1,) of a Roof of 40 feet span and (Fig. 2,) one of 60 feet span, are two of the best examples of the system that could be selected to shew the detail of construction, as both have been executed recently. Leaving the Skylight of the latter for future remarks, the parts of the second system consist of

Wrought Iron—2 Rafters of Rolled ⊤ Iron,
Struts of ditto. (No. and dimensions varying with span,)
1 Tie Rod,
1 King Rod,
Queen Rods,
and coupling plates to Rafters and Struts.

Cast Iron—2 Shoes.
Ridge Cap and Ridge Piece.

57. THE RAFTERS

differ in Section according to the span; No. 1 in the Table may be taken as the maximum of substance for a Roof of 60 feet, and No. 3 as the minimum for a 40 feet span. (Pl. 4, Sections 1 and 3.) The Web is punched at the proper distances for receiving the bolts connecting it

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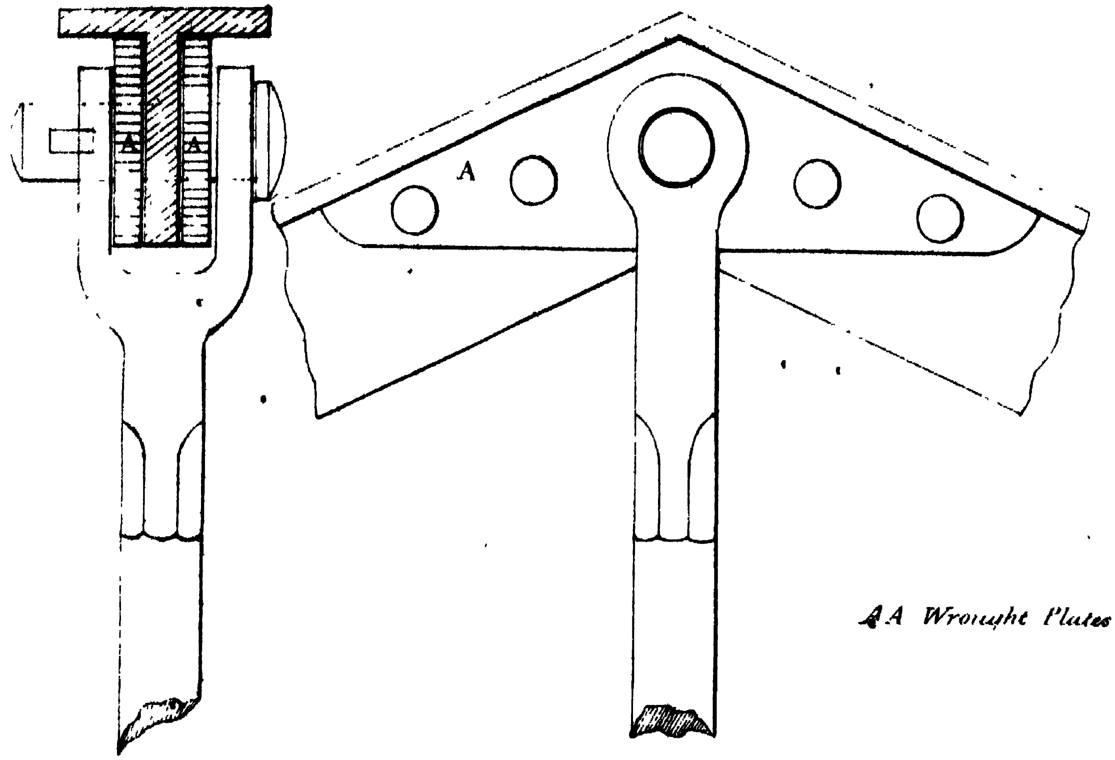
with the Struts and Queen Rods, the upper ends being rivetted together by means of a Wrought Iron plate on each side,

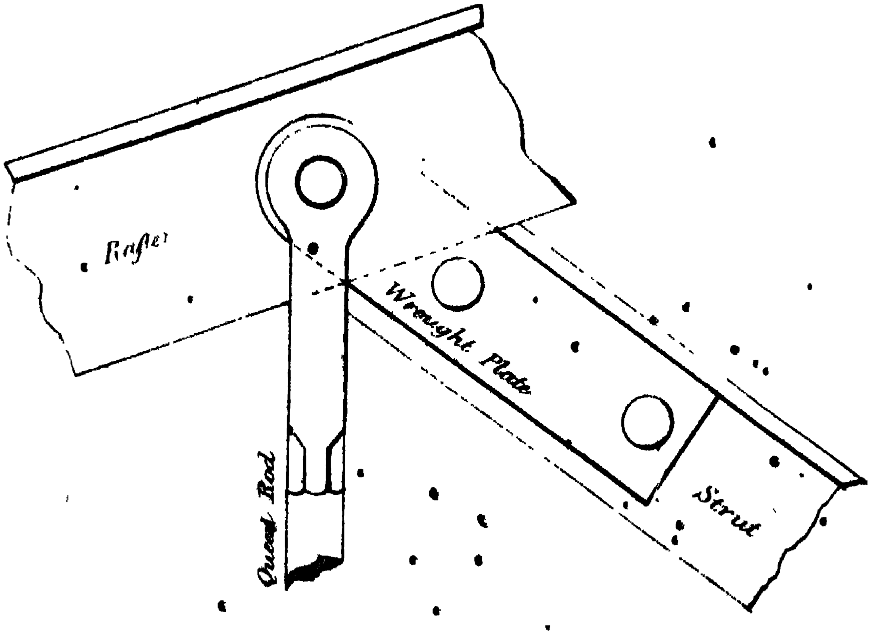


and prepared so as to receive the King Rod bolts; the lower ends are tapered off and secured to Shoes or Girders as the case may be.

58. THE STRUTS

in this system are of ⊤ Iron.* In Pl. 4 are given the Sections of the Struts used in the Roof of 60 feet span, the principal one is No. 5 in the Table, the other two might be No. 3, though the Section in the Plate gives the Table [illegible]″ × $\frac{3}{8}$″, and the Web $1\frac{3}{4}'' \times 1\frac{1}{2}''$, a little too stout. The Struts (Pl. 5, Fig. 1,) are No. 4 of the Table.

59. The connexion of the Struts with the Rafters by means of Wrought Plates is correctly shewn below



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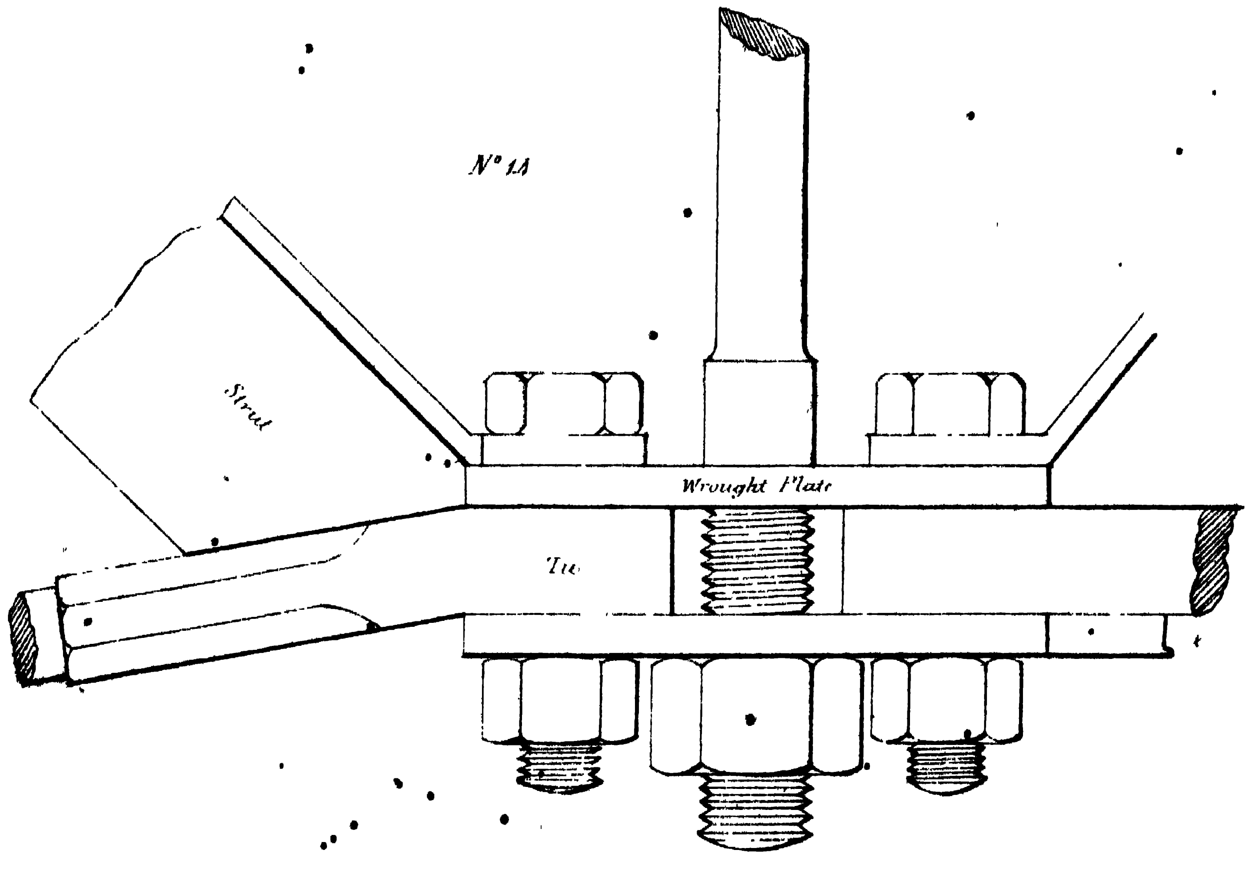
* There are examples of the Struts being of Cast Iron, and with a due regard to lightness and strength, they may be so made.

the Web of the Rafter being embraced between the plates by the Queen Rod, and the plates rivetted to the Struts, the upper ends of which are cut so as to fit close to the under edge of the Rafter. The Table of the lower ends is prolonged horizontally, and punched to receive the Queen Rod connecting them with the Tie. Wedge-shaped washers of Iron are introduced above and below the Tie, to bring the Nuts square on to the screws, the Tie Rod not being horizontal (vide Art. 104.)

60. THE KING ROD,

Suspended from the bolts passing through the plates which connect the upper ends of the Rafters, is secured through the central coupling plates, on the circumference of which are the lower ends of the principal Struts forming connexion between them and inner ends of the Tie, as shewn below


No 14

The King Rod in this example is 1⅛″ diameter. In some instances, as below,

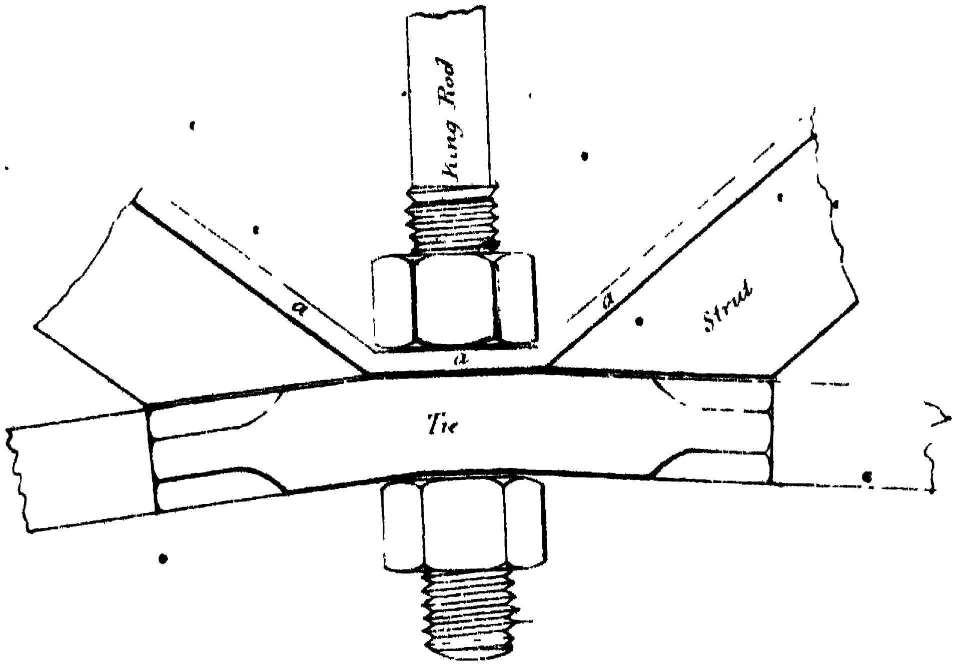


Table of Struts a a a forged for the

the principal Struts are forged together at the lower ends, and the King Rod passing through the Horizontal Plate thus formed, connects them to the Tie, which is here in one piece.* Diameter of King Rod ⅞″.

61.

THE QUEEN ROD,

or Suspension Rod. In the 60 feet Span Roof these Rods are of two dimensions of Round Iron, the largest being ⅞″ and the smaller ¾″ diameter; that of the 40 feet Roof being only ⅝″ diameter. These upper ends embrace the connecting Plates of Struts and Web of the Rafters by means of Bolts and Keys, and the lower ends pass through the Horizontal Table of the Struts, forming the junction with the Tie Rod. The screwed ends of these Rods enable a perfect adjustment to be made of all the parts after the principals are in position.*

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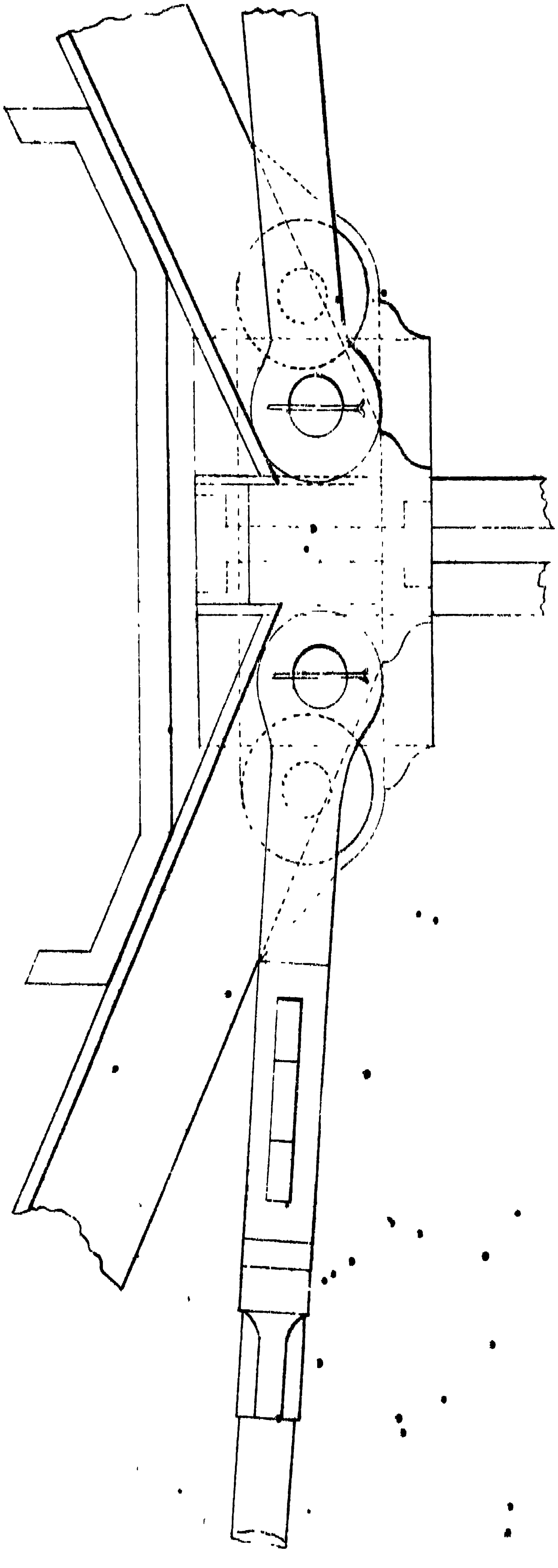
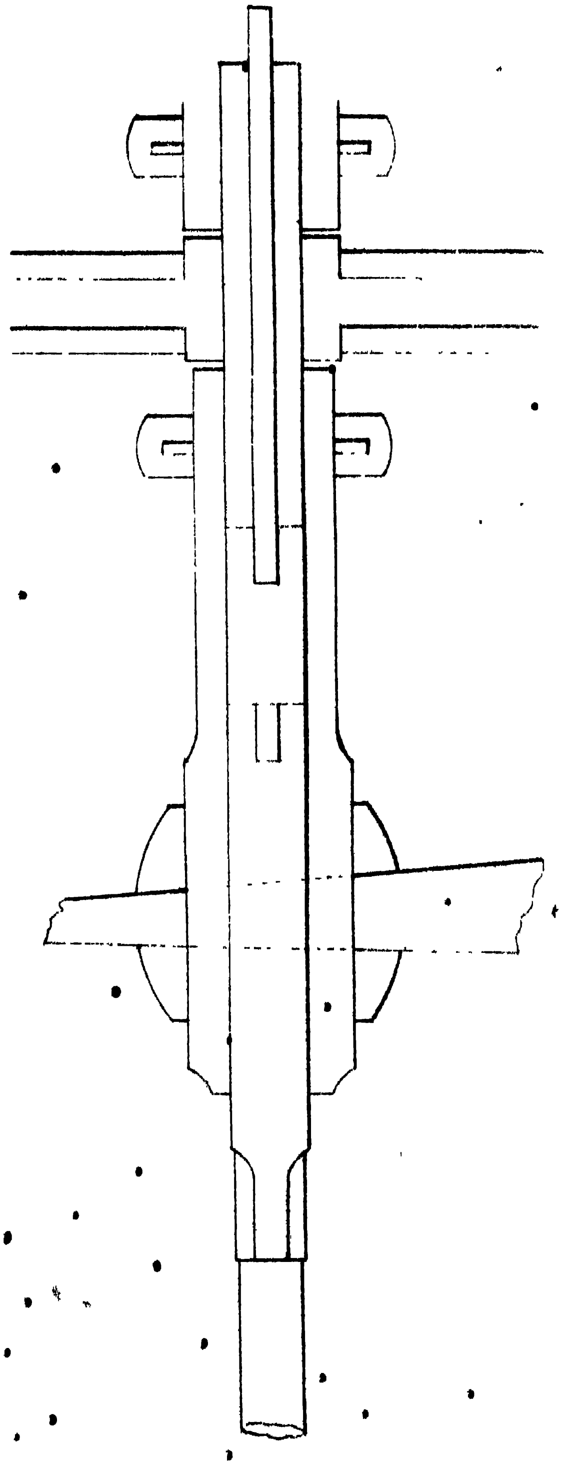
* The principals are put together on the ground, before being placed in position on the Walls of the Building.





62. THE TIE ROD

of a Roof of large Span (Fig. 2, Pl. 5,) is in two lengths, the junction being completed by means of a pair of Wrought Iron Coupling Plates, $\frac{1}{2}$ inch thick, holding the lower ends of Struts pierced for the reception of the King Rod. In a smaller Span (Fig. 1, Pl. 5,) the Tie is in one length, eyes are forged in the centre and at the proper distances for the reception of the King and Queen Rods. The Tie, in the former instance, tapers from the extremities of the Span towards the centre; the diameter of the outer ends $1\frac{3}{8}$,″ that of the next length $1\frac{1}{4}$,″ and at the inner end $1\frac{1}{8}$″ being in proportion to the degree of tension each part has to bear. The diameter of the Tie in the latter example is $1\frac{1}{8}$″.

63. The mode of securing the Tie Rod to the Shoe has been pointed out under the head of "Shoes," in the other method. (Art. 48.)

64. On the opposite page is shewn a mode of connecting the Tie Rod to Links; (which are used in the case of a double line of sheds, and sometimes forming part of an Iron Corbel built into the Wall; a pair of $\frac{1}{2}$″ Plates are bolted to the link and fastened at the distance of 6″ to the end of the Tie by means of a Gib and Wedge Key. This allows a certain flexibility, but is more adapted to the fixture of Cross Braces acting as Wind Ties.

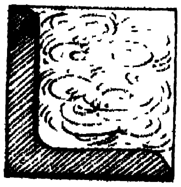
THE SHOES

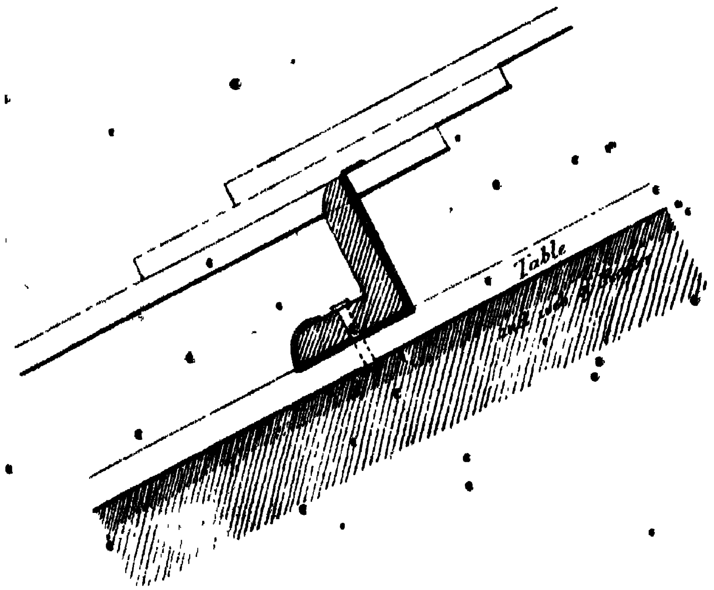
of Cast Iron, the form of which is suited to the mode of adjustment of Ties and Rafter considered most advisable: several examples and forms of Shoes are given in the Plates before alluded to, each well adapted to its purpose; they are strengthened by Side Ribs cast on them.

66. ANGLE IRON OR LATHS.

The coverings on these Roofs, whether Slates, Tiles or Zinc, are laid on Laths bent to an angle in the Rolling Mills (Section Pl. 5,) and cut to the lengths of the bearings between the Rafters to which they are rivetted (Pl. 4, Fig. 3,) is a Section of Iron used for this purpose $\frac{1}{4}$″ thick, the weight per foot is $1\frac{1}{2}$ lbs. only—the length of the under side is $1\frac{1}{4}$″ and the perpendicular side $1\frac{1}{2}$″.

This form has been adopted as the strongest, after various experiments on the same thicknesses, bent at angles varying from 135° to 90°. In laying the covering on Roofs, a practice was at first common of completing the square of which the Angle Iron forms two sides, by means of wood laid in; but the wood being liable to decay, it was discontinued, and a firmer mode of fastening the Slates and Tiles was adopted as follows:





Copper Slips $\frac{1}{16}''$ thick and ¼″ wide (shewn in red in the above figure) are passed through the upper parts of each Slate or Tile, down the rear of the Angle Iron and bent over the foot of it, by this means the Slates or Tiles are entirely secured from the effects of wind, and the Roof may be safely walked over for repairs, &c.

The Ridge Piece and Ridge Cap have been before described. (Art. 53.)

67. The weights of a Truss of each System and its parts, are accurately given below, shewing the lightness of the construction.

FIRST METHOD.

Roof 40 feet Span.

Wrought Iron. *Table.* *Web.*	Cwt.	Qr.	lb.	Cwt.	Qr.	lb.	Cwt.	Qr.	lb.
2 Rafters T rolled……… 2½″ … 2⅛″……	1	3	20						
2 Bent Tension Rods and Nuts, ……………………	0	3	0						
1 Tie Rod, ¾″ diameter, ………………………	0	0	26						
42 Rivets, ⅜″ diameter,…………………………	0	0	1						
12 Bolts and Keys to King-head and Shoes, ……	0	0	4						
Cast Iron.				2	3	23			
1 King-head,………………………………	0	0	20						
2 Shoes, ………………………………	0	0	16						
2 Struts, ………………………………	0	3	0						
				1	0	8			
Total,………							4	0	3
Add weight of Angle Irons for one space, ………………							2	2	0
Grand Total,……							6	2	3

The Angle Irons in this Roof were 15½ inches apart, and 6′ 8″ from centre to centre of Trusses.

N. B. The above refers to (Pl. 2, Fig. 2,) shewing a Roof of 40 feet Span on 1st system.

68. SECOND METHOD.

Roof 60 feet Span.

Wrought Iron.	Cwt.	Qr.	lb.	Cwt.	Qr.	lb.	Cwt.	Qr.	lb.
2 Rafters* (for Section vide Table) No. 1, ……	5	2	0						
6 Struts, ditto,………………………………	3	0	14						
Tie Rod and Keys,* ………………………………	2	3	16						
1 King and 4 Queen Rods,† ……………………	0	3	17½						
7 Pairs Connecting Plates for Rafters and Struts,	0	0	19						
Centre Coupling Plate, ………………………………	0	0	12¼						
Bolts, Pins, Rivets, &c.,………………………………	0	0	19¼						
Cast Iron.				12	3	14			
King-head,………………………………	0	0	12						
2 Shoes, ………………………………	0	2	0						
				0	2	12			
Total Weight of Principal,……							13	1	26

N. B.—The above refers to (Pl. 5, Fig. 2,) shewing a Roof of 60 feet Span on 2d system.

* Outer diameter of Tie,………………………… 1⅜ Inch.
Centre ditto, ………………………………… 1¼ „
Inner ditto, ………………………………… 1⅛ „

† Diameter of King Rod, ……………………… 1⅛ Inch.
Ditto Queen ditto, ……………………… ⅞ „

69. The expense of these Wrought Iron Roofs in London is as follows, and being unable at present to foresee the mode in which it may be intended to supply any demand in India, the English rates are here retained. The date is, I trust, not far distant, when the cost can be given in Rupees.*

70. Rate of 100 superficial feet of Iron Roofing, such as is shewn in (Pl. 5, Fig. 2,) 60 feet span, measured *horizontally* on the plan of the building £7-15-0, including Angle Irons and Gutters. The same with *Skylight* about £ 9-0-0.

71. Ditto ditto ditto as shewn in (Pl. 5, Fig. 1,) 40 feet span £7-2-0, with Angle Irons, but exclusive of Skylights.'

72. Ditto ditto ditto as shewn in (Pl. 2, Fig. 2,) 40 feet span £6-5-0. The Skylights being an additional expense of about £1-0-0 per 100 superficial feet. The measurement in all is horizontal.

73. It is necessary to state briefly the mode of putting the principals together to prevent derangement of the parts, and as a caution against the nuts and rivets receiving final adjustment, previous to their being placed in position.

74. Each principal is put together on the ground, the Shoes and ends of Rafters being supported a few inches above it.

In the fist system, the Rafters are fist adjusted to the King-head and Shoes, then laid on to upper ends of Struts and Bolts dropped through ; the ends of Tension Rods are put through the Shoes (or on to the Rafters, as the case may be) and King-head, the nuts being put on loosely, and in conjunction with the Tie bolted into the lower jaws of the Struts. In raising this Truss, a stretcher of wood, forked slightly at each end, should be laid on to the Tie, pressing against the lower ends of the Struts, to prevent the tendency of the two sides to close on each other while placing the Truss on the walls.

75. In the second system, the Rafters are laid together at the ridge, with the angle plates and rivets loosely put in, which, with the King Rod and its bolt being put on, will give the span at the feet. Tie Rods are then put through the Shoes, (nuts loosely put on) and fitted to centre coupling plates with the lower ends of large Struts. Rivets are dropped through the upper ends of Struts, but not fastened, the upper ends of Queen Rods are then adjusted, and lastly their lower ends, with those of the smaller Struts, the screws may then all be tightened, but not to the full extent necessary, and angle plates rivetted.

76. Care must be taken in hoisting the principals, not to lift them by the angle or other points of connection, but by the spaces between.

77. SKYLIGHTS.

Amongst the various buildings to which this mode of Roofing is applicable, there are many in which it is desirable to introduce Ridge or Skylights, such as extensive Store Rooms, Workshops, Public Offices, Halls, &c. ; the present article is therefore descriptive of the different kinds which have been adopted. The more lofty kind, such as is applied to the Roof in (Pl. 5, Fig. 2,) has sloping louvres, or, they may be termed Jalousie Sockets, cast on the standards for the admission of air at the sides, and may be either covered in above, similarly to the other parts of the Roof, or glazed. This Syklight, though executed in England, might be too lofty to be recommended for Indian purposes, where the force of the wind is so much greater. (Pl. 3,) exhibits four kinds, of very general application, which may be used according to circumstances. The Standards are necessarily of Cast Iron, as is also the Ridge Cap, and in those where the upper surfaces are glazed, the frames are cast in lengths equal to the space between two principals. The Standards are bolted to the Rafters of the Roof either by 2 or 4 bolts, according to the weight and extent of superstructure, (Fig. 3) shews the addition of a Skylight of 4 louvres to the 2d system, the Standards of which are 1½ feet high, the Roof is for the reception of glass.

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* Estimates of the cost of manufacturing these Roofs at the Iron Bridge Yard in Calcutta, have been circulated lately, the rates of which are but slightly in excess of the London rates.

78. In (Fig 1, Pl 3,) the Standards are dispensed with, the means of opening and closing from within are by a moveable lever bar bolted to the end of the smaller Rafter, on which bar there are two rests, the upper with a curve upwards, the lower curving downwards; thus the upper one catches the under side of a projection on the bracket and keeps the Skylight closed, as on the right hand side of (Fig 1,) and the lower catch of the lever bar rests on the upper side of the said projection, keeping the frame secure in an open position, as is shewn on the left side. There is a great reduction of metal in this latter plan, and under circumstances where the structure is light, it will be found preferable.

(Fig. 4,) is illustrative of a Skylight of less altitude than (Fig. 2,) and was erected on the Roof shewn in (Pl. 2, Fig. 1.)

WIND TIES.

79. In Buildings or Sheds of considerable elevation and open to the weather, such as Dock Yard Sheds or lofty Workshops, exposed at the sides and ends, cross braces, called Wind-ties, are used to stiffen the construction.

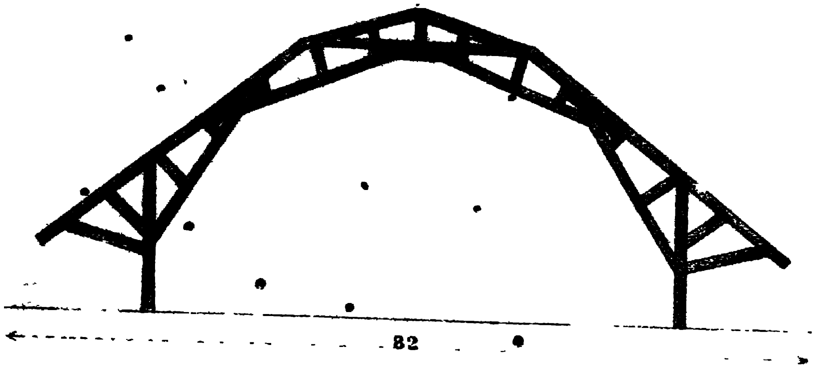
80. (Pl. 4, Fig. 1,) shews the application of a Tie of this kind to a Roof, the Rafters of which are 6 feet apart, the Wind-tie is of Rod Iron 1″ inch diameter, with a return at each end in opposite directions, corresponding with the lines of Tie Rods of the Trusses to which they are applied in the manner shewn in (Fig. 2,) one bolt being secured through the ends of two lengths of Wind-ties.

Wind-ties may either be applied from the centre of one principal to the outer extremities of the 2d removed from it; or from the extremity of one to the centre of the next, and then connected with the one in succession in a direction parallel to that of the Shed.

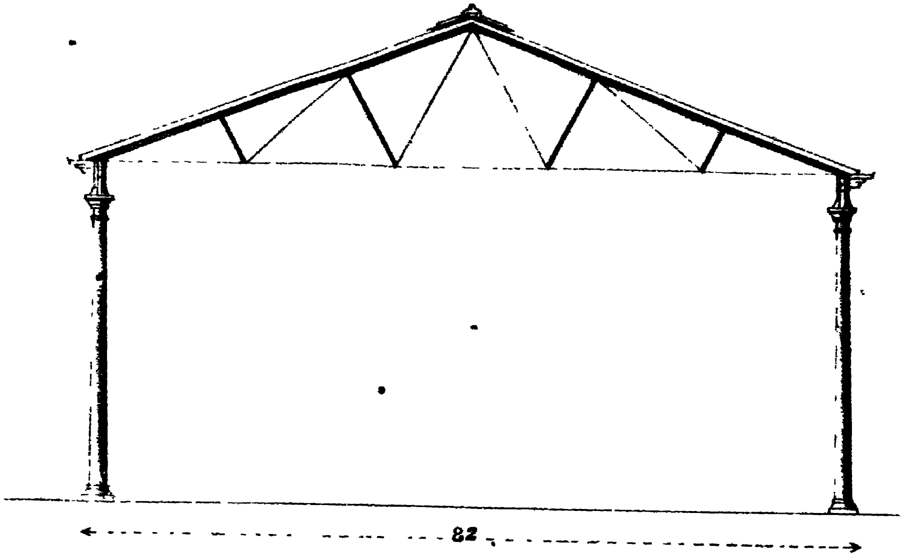
They are sometimes applied from the centre of a Truss to Brackets in the wall, 3 or 4 feet below the level of the line of Tie Rods, as shewn by the dotted line *a b* in (Pl. 7,) being in prolongation of the Tension Rod.

81. The introduction of these Roofs to the Slips and Sheds in H. M. Dock Yards, was stated at the commencement of this Memoir (frequency of fires and loss of public property having drawn the attention of Government to the expediency of the measure) and two plates (6 and 7,) are given as illustrative of the extent of the application.

82. (Pl. 6,) is on the 2d System, a triple Shed, the centre Span or Slip being 37 feet, and Side or Store Sheds 18 feet each—they are supported on hollow Cast Iron Columns, the centre ones being 10″ and the outer ones 6″ diameter at the base—low Skylights are applied to this Roof. Cross Girders connect the columns longitudinally, through which the ends of the Tie Rods are bolted—the inner ends of the Ties of the Store Sheds pass through the centre columns.



Trussed Dock Slip of Timber



Wrought Iron Roof for Dock Slip

Both these Sketches are to the same Scale 82 feet Span

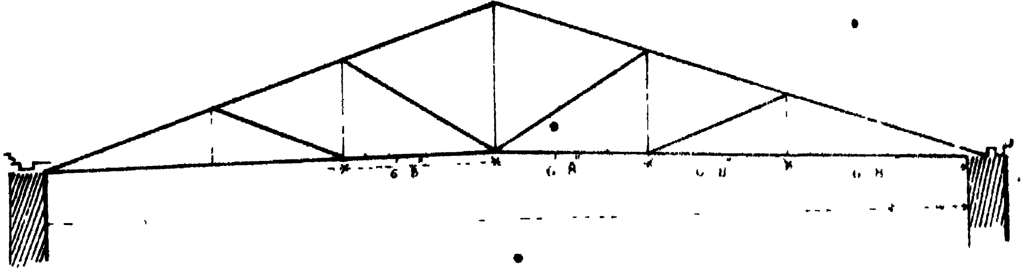
H. Goodwyn.

83. (Pl. 7,) shews a splendid Roof for a Slip in the Pembroke Dock Yard, it is 82′ 6″ in span, and also one of a series of three parallel Sheds all of the same span. The height of the eaves is 50 feet. The Rafters are of Rolled Iron, with a double table, the depth being 6″. The Struts are 4″ in depth, the Tension Rods are 1⅛″ diameter, and the Tie Rod tapering from 1¾″ at the extremities to 1⅜″ in the centre. This Roof is an extension of the first system, and in order to avoid the weight that would result from the Cast Iron Struts of this system, Wrought ⊤ Iron has been introduced, and the Tie Rod has been kept horizontal. The whole construction is accurately shewn in the plate : no further comment is required on the practicability of covering vast as well as small spaces by means so simple, durable and efficacious. Who can contemplate this Roof, and not be convinced of the superiority of the system over Timber for this and other purposes. (Vide annexed Sketch.) The Timbering of a Dock Yard Shed is a mass of heavy frame-work of complicated and expensive construction, and liable to destruction at any moment from fire.

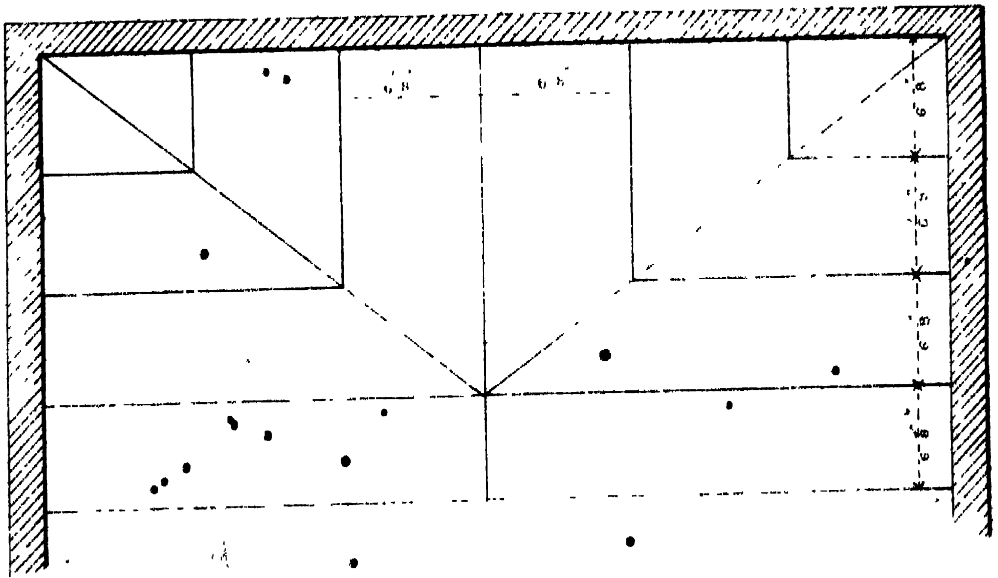
84. HIP ROOFS.

To construct a Roof with Hip Rafters of Iron, the dimensions of the parts must be thus previously determined.

Supposing the Span to be 40 feet, care must be taken to have the distances between King and Queen Rods equal to that between the centers of principals, as below—



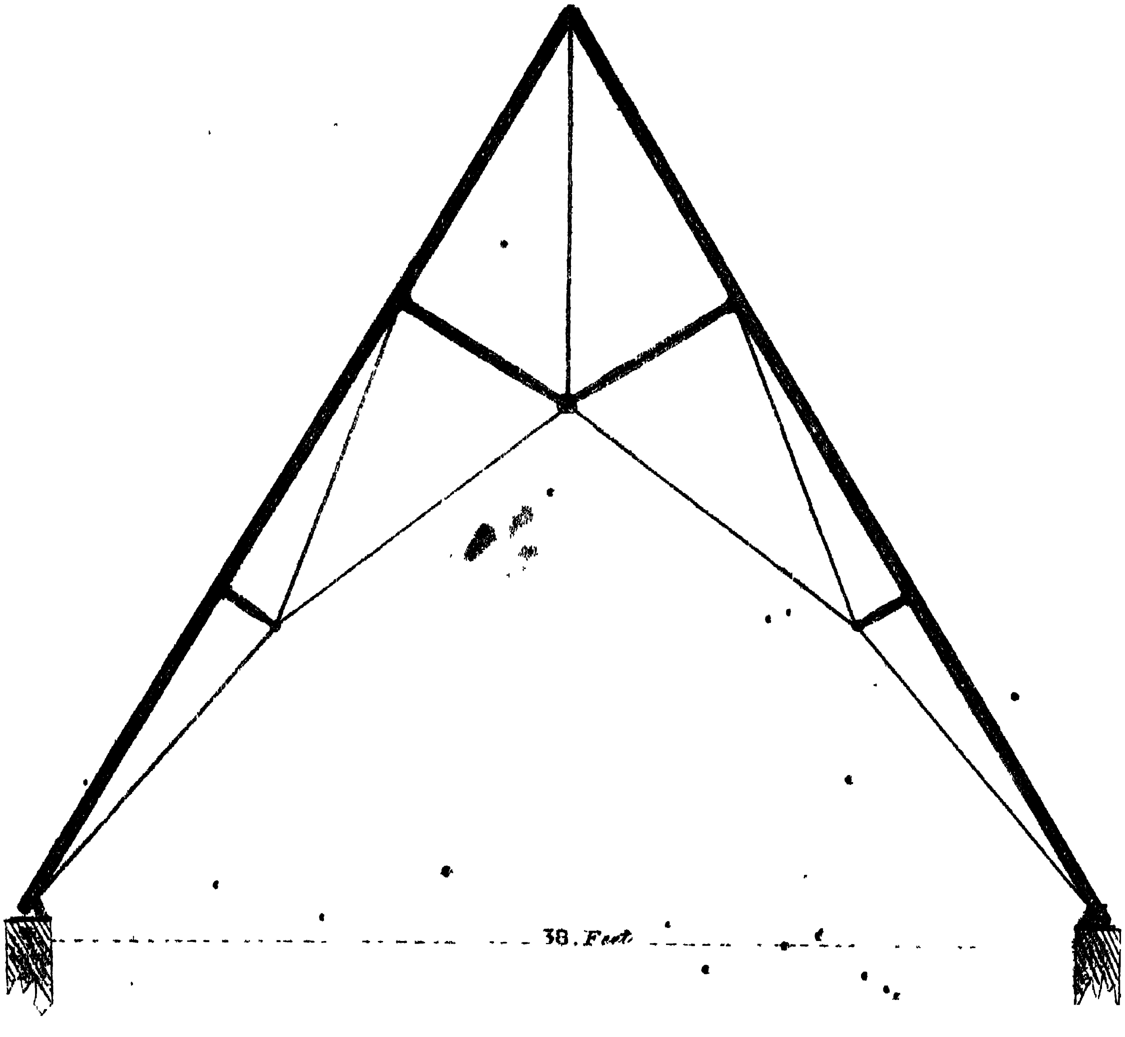
The plan will shew thus—



by this means all the King and Queen Rods will range in correct lines, and the slope of the Hip will be the same as the slope of the sides of the Roof (Pl. 8,) shews the construction of a Hip Roof of Wrought Iron.

85. Fig. 1 is the plan of the position of the Rafters, &c., radiating from the termination of the rectangle. Figs. 2 and 3 are the elevations of the principals on the 1st System.

Design for an Iron Roof in the Gothic Style



86. The detail is given to a scale ¼ full size, and exhibits (Fig. 4,) the connexion of the principals with the King-head, its form and mode of securing the upper end of the bent Tension Rod, (Fig. 5,) the central Plate for receiving the Ties of the radiating Trusses, and (Fig. 6,) the mode of junction of the auxiliary Rafters with the main.

The Rafters in this plate are supposed to be of the double Section treated of in the next Chapter (Art. 92.)

87. In order to shew the universal application of the System, annexed is a design for a Roof on a Gothic Building of the early English style. The sides of the Roof forming an equilateral Triangle with the base, the framing for which is so adjusted as to give the full effect to Strut and Tie, so that the action of the weight shall strain the Ties in the direction of their length.

88. The two systems of Wrought Iron Roofing have, in the foregoing examples, been so variously applied, and the several parts laid down with such attention to detail, as to exhibit the ready means of adapting them to Buildings of any form and spans of vast extent, the result has been, I hope, to verify the assertion in the Introduction of the subject, that there exists a sure and easy mode of constructing permanent and elegant coverings as substitutes for the rapidly decaying material now in too general use.

89. The various designs, (and I may add the study that has been given in perfecting them) most truly agree with the motto in the first page of this Memoir.

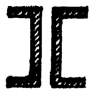
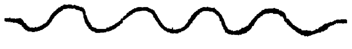
On the Application of Wrought Iron Roofs as adapted to such Buildings as form the Dwellings of Europeans in India.

90. Roofs such as have been described having been applied in England to a variety of Buildings, and their peculiarly light construction rendering their adoption a measure of more than probable advantage in India, where frequent destruction of property, public and private, takes place, and building material is very perishable, I was induced to attempt such a modification and improvement on the T Rafter as should render these Roofs serviceable for Buildings inhabited by Europeans; the Rafter already treated of with only a single Table, not affording sufficient protection from the Sun.

91. Of the adaptation of Iron Roofs to other Buildings, such as Store Rooms of all kinds, Workshops, Sheds and other Buildings where protection from fire or decay is an object, no further remarks are necessary than those already set forth, and the detail of which has been given; the examples discussed being such as may be readily adopted. The case however is different with regard to those Buildings meant as residences for Europeans; for Iron Roofs, with no other covering than tiles, would not afford sufficient shelter from the heat of the Sun. It became necessary in considering the matter, to arrange for an inner covering, providing at the same time means whereby the heat should not be transmitted to it from the external one; and after the rejection of various plans, the following arrangement was found to unite the greatest probabilities of success.

CONSTRUCTION.

92. Pl. 9, Fig. 1. The Rafter is designed with a table or flange at the lower end of the web on which to rest an inner ceiling, and as this table could not be attached to the ordinary

⊤ Iron on account of its preventing the connection of Struts and Tie Rods, it became necessary to divide the web into two thicknesses of ¼″ each, thus  the tables being 1¼″ long to support a ceiling, and the two halves at an interval of 1½″ apart, in which the Struts and Tie Rods just fit, and are secured by bolts connecting them and the half rafters together. The inner ceiling then remained to be determined on, and the common Sheet Iron or Zinc plates proving too weak for the span between the trusses, Iron of a novel and strong form was chosen such as is shewn in Section  and called "Corrugated,"* the plates, are rolled into a serpentine form of various thicknesses, and being thereby rendered stiff and strong, 1-16th of an inch was found sufficient for this purpose; plates of the Corrugated Iron are rivetted to each other, and to the upper surface of the lower table, and the space thus formed between the inner ceiling and covering of the roof to be filled in with broken charcoal or other nonconductor of heat, thus forming a cool and efficient roof.

93. The charcoal should only be filled up to the level of the top of the rafter, thereby enabling any heated air that may find entry, to pass off between the division of rafters and under the ridges.

94. Fig. 2. Shews the mode of introducing the Strut between the divided rafter, and Fig. 3, the connection between the rafter and shoe; in which additional support is afforded to the Rafter by means of a projecting heel against which the half rafters abut firmly, and the bolt secures the whole.

The above has reference to the 1st System.

95. Fig. 4. Shews the application of the divided rafter and Corrugated Iron to the Second System, in elevation. Fig. 5, is a section through the ridge, shewing the mode of fixing the King-head in this case, also the ridge-cap and plates with the transverse bolt.

96. Fig. 6. Shews the junction of the Struts (which, as before, are of ⊤ Iron,) and Queen rods with the Rafter, and Fig. 7, the connection of the lower Strut where the Queen rod is not required.

97. Figs. 8 and 9, are the front and rear elevations of the Shoe with the Rafter affixed, the latter Fig. also shewing the end of Tension Rod passing through the Shoe below the Rafter.

98. With these exceptions, the construction of the Trusses is the same as before described.

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* The Patent for this Iron is expired, and it can now be purchased at a moderate rate.

IRON GUTTERS.

99. The introduction of Iron as the component part of a Roof affords an excellent opportunity for the introduction of efficient Gutters, and thus draining the rain water from the roof instead of permitting it to deface the walls as is too generally the case, and adverted to in the Introduction to this Memoir.

100. Suppose Fig. 10, Pl. 9, to represent a half Truss of a two storied Building—at A is shewn in Section a Cast Iron Gutter, which is rivetted on to the Table of the Rafter, and laid the whole length of the eaves. The roof of the upper story is supported on Cast Iron Columns which are hollow, and in the Gutter, just over the heads of these columns, are apertures conducting the water through the columns, to the head of a Pipe at B. Fig. 10, inserted in the wall, and which is connected with a proper drain at the base of the Building.

101. The Cast Iron Columns, if the Building is light, may form the appropriate supports to the Verandahs of an upper story by themselves, and if the Building is of a massive description, a plain pipe may be introduced from the eaves of the Roof through the whole height to the drain below, passing through either a column of Masonry or Wall.

102. If the Building is one of a single story, the application of the Gutter and Column, or pipe is made in precisely a similar manner, as it is only supposing the hollow Iron Column to form the support to a Verandah on the ground floor, or where a wall exists the pipe is substituted.

Figs. 11, 12 and 13 shew the details of the Gutters on a larger scale, viz.

Fig. 11, a Section through one of the rain water heads leading to the pipe or column below, shewing the joint of the water head with the Gutter.

Fig. 12 is a plan of the same.

Fig. 13 is a Cross Section through the Gutter shewing the dimensions of the Metal.

The following Estimates shew the weights of Metal in a single Truss on both systems, for a span of 45 feet each, the Trusses being placed 6 feet 8 inches apart.

The superficial measurement on a ground plan being equal to 300 feet horizontal space covered by one Truss, and its complement of Angle Irons or Laths.

1st METHOD.

		Cwt.	Qrs.	lbs.	Tons.	Cwt.	Qrs.	lbs.
1	Truss, including the Laths complete, sufficient to cover 300 feet superficial measured on plan.							
	Wrought T Iron in Rafters,	3	3	7				
	Wrought Iron in Tie Bar,	0	2	0				
	——— ditto in Bolts,	0	1	0				
	Angle Iron,	5	3	3				
	Corrugated Iron,	18	2	14				
	Rivets,	0	0	4				
					1	9	0	0
	Cast Iron in King Heads,	0	0	21				
	—— ditto in Shoes,	0	1	7				
	—— ditto in Ridge,	0	1	11				
	—— ditto in Struts,	0	2	0				
	—— ditto in Gutters,	1	2	17				
					0	3	0	
	Cast Iron in R. W. Pipes, Bends, R. W. Heads, &c.,				1	19	3	
	Wrought Iron Nails for ditto,				0	0	2	

This has reference to Fig. 10, Pl. 9.

2nd METHOD.

		Cwt.	Qrs.	lbs.	Tons.	Cwt.	Qrs.	lbs.
1	Truss, including the Laths complete, sufficient to cover 300 feet superficial of Building, measured on plan.							
	Wrought T Iron in Rafters,	3	2	24				
	——— ditto in Struts,	1	3	7				
	——— ditto in Tie Bars,	2	1	11				
	Bolts and Connecting Plates,	0	0	14				
	Angle Iron,	4	3	14				
	Corrugated Iron,	17	0	11				
	Rivets,	0	0	3				
					1	10	0	0
	Cast Iron Shoes,	0	1	0				
	Cast Iron Ridge,	0	1	14				
	Cast Iron Gutters,	2	0	21				
	Cast Iron Shoes for Ridge,	0	0	7				
					0	2	3	14
	Cast Iron in R. W. Pipes, Bends, &c.,				0	11	2	0
	Nails for ditto,				0	0	0	14

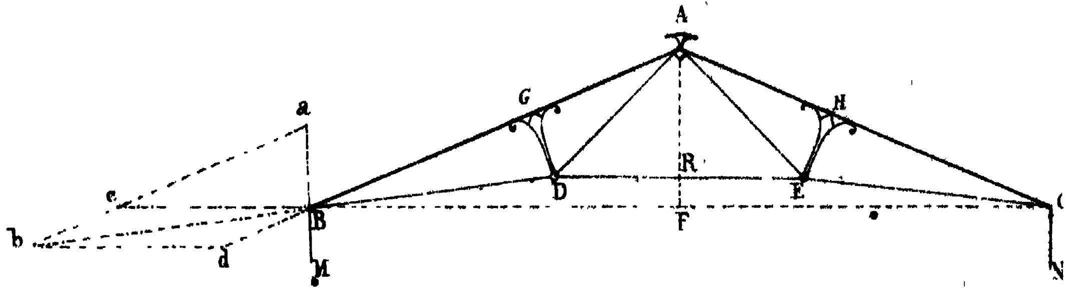
These Trusses, it must be remembered, are for Roofs to the Dwellings of Europeans, with an Inner Ceiling.

The difference of weight between these and the Trusses given in Art. 70 is caused by the double Rafter and Corrugated Iron.

Investigation of the Tensile and Compressive Strains which act upon Rafters, Tie and Tension Rods of the Wrought Iron Roofs

103. The weight of the Roof being given together with the directions of the various parts, by the laws of Equilibrium the forces which act on the different parts can be determined, and thence the necessary section be deduced.

If three forces act at a point and keep it "in Equilibrio" and a Triangle be formed by lines drawn in the direction of the forces, and one side represent its corresponding force, the remaining sides will measure in direction and magnitude their respective forces.



Let the truss with its proportional superincumbent weight $= 2$ w, $\angle$ BAF $= \theta$, $\angle$ D B F $= \varphi$, $\angle$ A D F $= \beta$. The columns M and N equally supporting the weight of the Roof $= 2$ w, must each sustain a pressure $=$ w. Let A B represent w, produce D B, C B, and draw a b, parrallel to A B—then a b will represent the strain on A B and B b the strain on BD, ac and B c will represent the same strains if B D E C be horizontal.

$$\text{a b : a B} = \text{w : : Sin. a B b} = \text{Sin. }(\varphi + 90) = \text{Cos. }\varphi : \text{Sin a b B}$$
$$= \text{Sin }(90\text{—}(\theta + \varphi))$$
$$= \text{Cos. }(\theta + \varphi)$$

$$\therefore \text{a b} = \text{w}\,\frac{\text{Cos. }\varphi}{\text{Cos. }(\varphi + \theta)} = \text{strain on A B.}$$

$$\text{b B : a B} = \overline{\text{w : : Sin. }\theta : \text{Cos. }(\theta + \varphi)}$$

$$\therefore \text{b B} = \text{w}\,\frac{\text{Sin. }\theta}{\text{Cos. }(\theta\ +} = \text{strain on B D.}$$

Now since there is Equilibrium at the point D the force in B D must be balanced by the forces in D R and D A, and $\therefore$ if we draw B d and b d parallel to A D and D R then b d will measure the force in D R and B d the force in A D.

$$\text{b d : B b} = \text{w}\,\frac{\text{Sin. }\theta}{\text{Cos. }(\theta + \varphi)} : : \text{Sin. b B d} = \text{Sin. }(\beta - \varphi) : \text{Sin. }(180\text{—}\beta.)$$

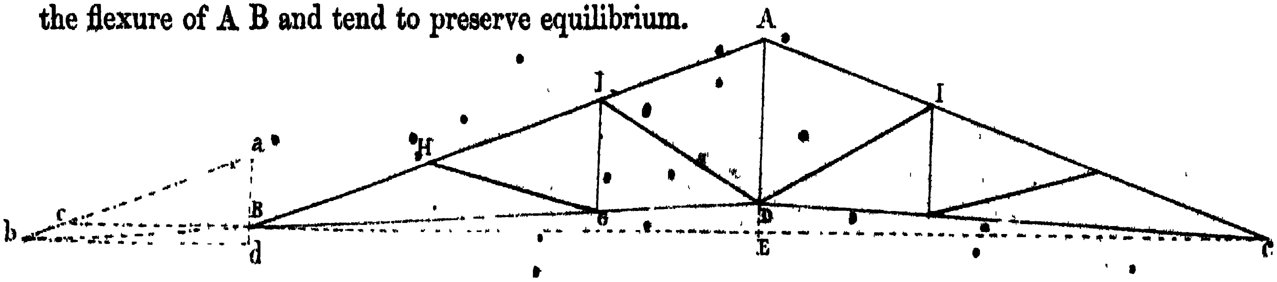
$$\therefore \text{b d} = \text{w}\,\frac{\text{Sin. }\theta\text{ Sin. }(\beta\text{—}\varphi)}{\text{Cos. }(\theta + \varphi)\text{ Sin. }\beta.} = \text{strain on D R and since the horizontal Tie Rod is equally acted}$$

on at its extremities by equal forces in opposite directions of $\text{w. }\frac{\text{Sin. }\theta\text{ Sin. }(\beta\text{—}\varphi)}{\text{Cos. }(\theta + \varphi)\text{ Sin. }\beta.,}$ the Tension of the whole length of D E will be equal to $\text{w. }\frac{\text{Sin. }\theta\text{ Sin. }(\beta\text{—}\varphi)}{\text{Sin. }\beta.\text{ Cos. }(\theta + \varphi)}$

$$\text{B d : B b} = \text{w. }\frac{\text{Sin. }\theta}{\text{Cos. }(\theta + \varphi)} : : \text{Sin. }\varphi : \text{Sin. }(180\text{—}\beta) = \text{Sin. }\beta.$$

$$\therefore \text{B d} = \text{w. }\frac{\text{Sin. }\theta\text{ Sin. }\varphi}{\text{Cos. }(\theta + \varphi)\text{ Sin. }\beta} = \text{strain on A D.}$$

and if A B be trussed by the rectangular strut D G, then the force exerted on D G, will be as the flexure of A B and tend to preserve equilibrium.



104. Take another Truss (the 2d system) for example. In this case if B a = w, as before and angles be denominated by the same letters (β being absent.) The strain on A B will be as before w. $\frac{\text{Cos. } \phi.}{\text{Cos. } (\theta + \phi)}$, that on B D. ditto w. $\frac{\text{Sin. } \theta.}{\text{Cos. } (\theta + \phi)}$, and that on A D will be $= 2$ a B $+$ 4 Bd $= 2\text{w} + 4\text{w.} \frac{\text{Sin. } \theta \text{ Sin. } \varphi}{\text{Cos. } (\theta + \phi)} = 2\text{w.} \left(1 + 2 \frac{1}{\text{Cos. } \theta \text{ Cos. } (\phi - 1)}\right) = 2 \text{ w.} \left(1 + \frac{2}{\text{Cotant. } \theta \text{ Cotant. } (\phi - 1)}\right)$ as will be seen by resolving forces in A B and A C, and also in B D and D C, and adding them together for the total force exerted on A D.

Had B D C been horizontal, then the force in A B $=$ a c $=$ w. $\frac{1}{\text{Cos. } \theta} =$ w. Sec. θ—also in B C $=$ w. tan. θ, and in A E $=$ 2 a B $=$ 2 w., which theoretically proves that the nearer the horizontal the Tie-beam becomes, the less are the strains; but also of course the heavier the Struts and Rods, and principles of economy induce a medium to be taken, combining lightness and a sufficiency of strength.

SUPPLEMENT.

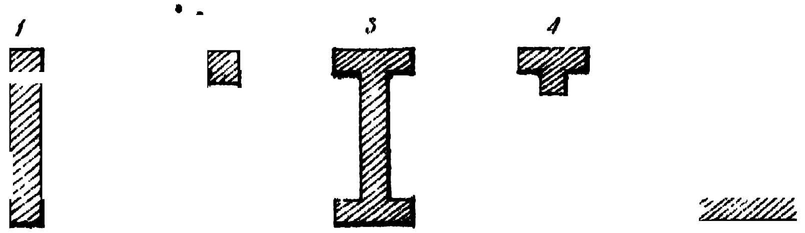
105. Whilst on the subject of Iron Roofing, I may notice the examples of horizontal Cast Iron Girders as applied to Roofs that have come under my notice, nor are they confined to Roofing alone, for many Public Buildings, and lately the ground floors of private dwellings have been supported by this means, the intervals being light arches of brick or tiles from 6″ to 9″ thick, thus preserving the upper stories from the effects of fire that may have its origin from below.

Previous to entering on a description of examples, I will extract the essential points of construction and mark the rules necessary to be observed in designing a Cast Iron Beam for a specific object, as laid down from the experience of Engineers, and detailed by Mr. Turnbull in an Essay on the five different Architectural Sections.

When a comparison is to be made between the elastic powers of different bars, or beams of the same form and material, it is necessary to keep in mind, that when the Transverse Section is rectangular "the breadth of the Transverse Section, drawn into the square of its depth; divided by the length of the beam, drawn into the measure of its elastic power, must be the same in all."

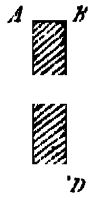
The constant number derived from Mr. Barlow's measure of Cohesion is 1000, and that by Mr. Tredgold is 850, the Test of actual experience has however shewn that a mean will approach nearest to the truth, for many Engineers have observed that beams constructed by Tredgold's rules have a redundance of strength, whilst those by Barlow are rather too weak; a claim therefore may properly be established for a preference to the mean which we will call 925.

The five forms of Section given below



are those most commonly used in Buildings for Girders, Bressumers, &c., we will now consider the relative values and proportions of the different Sections, and first of the

Complete Rectangular Transverse Section.



b = A B, the breadth of the Transverse Section A B C D in inches,

d = A C, the depth in inches;

l = the length of the beam, or rather, the distance between the points of support in feet, and w = the measure of its elastic power in pounds;

The number 925 having been admitted as a constant quantity, the value of the Equation in this case is

$$l\,w = 925\,b\cdot d^2 \quad (A)$$

Of the Open Rectangular Transverse Section.

Beams of this Section are sometimes cast open, that is, having a portion in the middle entirely left out, and it is a singular fact, that beams constructed in this manner are both stronger and stiffer than when cast solid from the same quantity of material, this at first sight seems paradoxical, but it is nevertheless true, and Engineers do frequently avail themselves of this property, when strength and stiffness are required with economy and lightness. Here follows the investigation.

Let b = A B, the breadth of the Transverse Section A B C D
d = A C, the whole depth ;
D = E G, the depth of the part left out,
l = the distance between the points of support,
and w = the measure of the elastic power.

Then if unity or 1 represent the force of extension and compression for the depth d; the Section being considered complete as in the preceding case, we shall have

$$d : D :: 1 : \frac{D}{d},$$

the force of extension and compression for the depth D.

Now, by referring to the equation marked (A) above, it appears, that the strength of a complete Rectangular Section, having the breadth b, and the depth d, is as $b\,d^2$; consequently the strength of another complete Rectangular Section, having the breadth b and the depth D, must be as $b\,D^2$; but the force of extension and compression for the depth d, is to the force of extension and compression for the depth D, as the resistance of the portion E F G H, is to the resistance of the same portion considered as a separate and independent Section, now we have already shewn that the forces of extension and compression are directly as the depths ; therefore by the equality of ratios, we have

$$d : D :: b\,D^2 : \frac{b\,D^3}{d},$$

the resistance of the part left out.

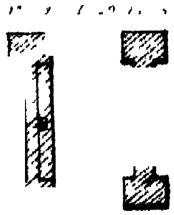
Now, the strength of the open Section is evidently equal to the difference between the strength of the whole considered as complete, and that of the part left out considered as a separate Section; but the strength of the whole has been shewn above to be as $b\,d^2$, and that of the part left out is as $\frac{b\,D^3}{d}$; therefore the strength of the open rectangular transverse Section is as $b\,d^2 - \frac{b\,D^3}{d}$; consequently, from our principle of comparison, the general formula involving the several condition, becomes

$$d\,l\,w = 925.\,b\,(d^3 - D^3) \text{—} (B).$$

Of the Complete **I** *formed Transverse Section.*

The next form of the Transverse Section now to be considered is, that which from its resemblance to the capital letter **I**, assumes the denomination of the **I** formed Transverse Section, and its solution as in the case of the Rectangular Section foregoing, branches itself into two varieties according as the Section happens to be complete or open. A Section of this sort when complete is formed by abstracting a rectangular portion from each side equidistant from the top and bottom of the Section, it possesses advantages similar to those possessed by the open Rectangular Section just mentioned, and the investigation proceeds on the same principles.

Let the strength be first determined as if the Section were entire, represented in Fig. 1, and suppose the portions A and B Fig. 1, to be abstracted from the whole, and brought together as in Fig. 2, then the strength of the united portions A and B Fig. 2, being determined in the same manner as we determined the strength of the whole in Fig. 1, it is obvious, that the difference between the strength of the whole Section and that of the abstracted portions must indicate the strength of the Section that remains in Fig. 3.



Let b = the whole breadth of the Section Fig. 1.
d = the whole depth;
B = the sum of the breadths A and B. Fig. 2.
D = the depth of those parts;
l = the distance between the points of support,
and w = the measure of the elastic power.

Then the strength of the Section, Fig. 1, whose breadth is b, and depth d, is as $b\,d^2$, and that of the Section, Fig. 2, whose breadth is B and depth D, is as $B\,D^2$; but by the principle of extension pointed out in the case of the open rectangular Section, we have

$$d : D :: B\,D^2 : \frac{B\,D^3}{d},$$

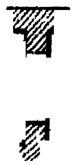
the resistance of the abstracted portions.

Therefore, the strength of the complete **I** formed Section Fig. 3, is as $bd^2 - \frac{B\,D^3}{d}$ consequently, from our principle of comparison, the general formula involving the several conditions, becomes

$$d\,l\,w = 925\,(b\,d^3 - B\,D^3).\ (C)$$

Of the Open **I** *formed Transverse Section.*

A Section of this form is only a combination of the open rectangular and the complete **I** formed Sections already investigated, and since each of those Sections possesses some important advantages, that which we are now considering must partake of an intermediate strength; that is, it must be weaker than the one and stronger than the other.



Let β = the breadth of the open part;
δ = the depth of that part;
l = the distance between the points of support,
and w = the measure of the elastic power.

Then, the notation remaining as in the last case, the strength of the open part, considered as a separate and independent Rectangular Section and modified for the effect of extension, is as $\frac{\beta\,\delta^3}{d}$, but the strength of the complete **I** formed Section has been shown to be as $bd^2 \quad BD^3$;

consequently the strength of the open **I** formed Section must be as $b\,d^2 \cdot \frac{B\,D^3}{d} - \frac{\beta\,\delta^3}{d}$; therefore, from our principle of comparison, the general formula involving the several conditions, becomes

$$d\,l\,w = \underline{925\,(b\,d^3 - B\,D^3 - \beta\,\delta^3)}. \quad (D)$$

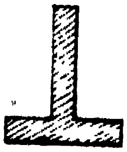
Of the Single Flanged or **T** *formed Transverse Section.*

Another sort of beam, of very frequent use in buildings is, that which has a single flange running along its upper or its under side throughout the whole of its length, and from the circumstance of its Transverse Section bearing a strong resemblance to our capital letter **T**, whether inverted or otherwise, it receives the denomination of the single flanged or **T** formed Section.

A beam of this Section is not strong in proportion to the quantity of material it contains, and since, on account of the neutral axis not existing at the middle of the depth, it becomes difficult to calculate, it ought to be very sparingly introduced, unless where circumstances of a very froward nature compel its adoption.

The general expression for this Section is

$$l\,w = 393\,b\,d^2 \text{ (*)} \quad (K)$$



Of the Proportions of the Parts of the Transverse Sections.

The equations marked (B), (C), (D) and (K), in their present form, are general, and apply alike to all dimensions of the Sections and any relation of the parts, but it is easy to show on scientific grounds, that the same quantity of material may be so fashioned as to attain any proposed augmentation of strength, setting aside the risk of imperfect casting, and provided the proposed augmentation and quantity of material be retained within possible limits; for we know, that the more nearly the upper and lower parts of the Transverse Section approach to a similar form and equality, the greater is the lateral strength, and if the parts can be so arranged and assimilated on each side of the neutral axis as to give a certain function of the consecutive differences a maximum, the form of Section will in that case be the most advantageous possible. Now we have already stated in regard of the open Rectangular Section, that when a certain quantity of metal is moulded into a beam of that form, it is both stronger and stiffer than it would be if cast solid; that is the case generally, but it is easy to perceive that there must be a certain proportion between the whole depth and the depth of the open part, and a similar proportion between the whole depth and the breadth of the Section in order to give the most advantageous strength, and when such proportion has once been discovered, the rules derived from it should be invariably employed, unless the situation is such as to preclude their application.

The general expression for the open Rectangular Transverse Section has been shown to be

$$d\,l\,w = 925.\,b\,(d^3 - D^3); \text{ see equation (B)}$$

and experience has established the fact, that the most advantageous proportions are those that give $7.d = 10.D$ and $b. = \frac{1}{2}(d - D)$; that is, when the Cross Section of the upper part is a square and equal to that of the lower part, and when the whole depth and that of the open part are to one another as 10 to 7.

Let the relations just stated be introduced in the above expression, and it becomes

$$l\,w = 608\,b\,d^2 \quad (F.)$$

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[*] The calculation, being long and intricate, is omitted.

And because the breadth $b = \frac{1}{2}(d—D)$, and $D = {\cdot}7\ d$; $b = \frac{3}{20}\ d$, this value of b finally constitutes the following equation.

$$lw = 91d^3 \quad (G.)$$

The general expression for the complete **I** formed Transverse Section has been shewn to be

$$d\,l\,w = 925\ (bd^3 — B\ D^3);\ \text{see equation (C).}$$

and by the principles of the maxima and minima of quantities, we find that the maximum strength of this Section with a given area, occurs very nearly in the state, when $5\ b = 8\ B$ and $7\ d = 10\ D$, that is when $B = 625\ b$ and $= D = {\cdot}7\ d$.

Let these values of B and D be substituted in the above general expression, and it becomes

$$l\,w = 726\ b\ d.^2\ (H).$$

The general expression for the open **I** formed Transverse Section, has been shewn to be

$$d\,l\,w = 925\ (b\ d.^3 — B\ D^3 — \beta\ \delta^3)\ \text{see equation (D).}$$

and the most advantageous proportions for this Section will evidently be obtained by conjoining those which we have shown to exist for the two preceding ones, the Section itself being nothing more than a combination of those two; now it is easy to show that these proportions will occur, when $D = 7\ d$; $\delta = {\cdot}7\ D$. or. $49d$;—$\beta = {\cdot}375b$. and $B = {\cdot}625b$ as before.

Let those values of B, D, β and δ be substituted in the above general expression, and it becomes

$$l\,w = 686\ b\,d^2\ (I.)$$

The equations thus modified for general practice, when brought into one view, will stand as below—

1. For the complete Rectangular Section, ... $lw = 925\ bd,^2$
2. For the open Rectangular Section, ... $lw = 608\ bd,^2$
3. For the complete **I** formed Section, ... $lw = 726\ bd,^2$ (L).
4. For the open **I** formed Section, ... $lw = 685\ bd,^2$
5. For the single flanged, or **T** formed Section, ... $lw = 393\ bd,^3$

Of the Sectional Areas.

Now, in order to ascertain the relative advantages of each Section, it will be proper to compare their computed strengths with one another when constructed of the same quantity of material, it is unnecessary in merely comparing the strength of the several Sections, to take the length into account, for since it is supposed to be invariable, the comparative results will be the same by considering the dimensions of the Sections alone. Let (a) in general represent the Sectional Area; then

The equations for the Sectional Areas may be exhibited in one view, (the calculations being intricate and consequently omitted.)

1. For the complete Rectangular Section, ... $a = bd$.
2. For the open Rectangular Section, ... $10\ a = 3\ bd$.
3. For the complete **I** formed Section, ... $16\ a = 9\ bd$ (R).
4. For the open **I** formed Section, ... $800\ a = 303\ bd$.
5. For the single flanged or **T** formed Section, ... $1000\ a = 379\ bd$.

The Comparison of the Relative Strengths.

We are now prepared for comparing relative strengths of the different Sections with one another under a given Sectional Area; for which purpose, we shall assume the general area equal to 24 square inches, and since it is impossible to assign theoretically a maximum limit to the complete rectangular form, we shall content ourselves by adopting the proportions which practice has discovered to be most commodious.

Now it has been observed by several eminent practical Mechanics, that when a Cast Iron Beam of a rectangular form is so constituted, as to have the breadth of its Transverse Section nearly one eighteenth part of the depth, the beam in that state approaches its maximum in stability and strength; let us therefore adopt the ratio of 18 to 1 as a standard, then,

For the complete Rectangular Section.

We have bd 24 and from the proportion just mentioned we obtain d : b :: 18 : 1 that is, $d = 18\,b$.

Let this value of d be substituted in the equation $bd = 24$ and it becomes $18\ b^2 = 24$ from which, by division and evolution, we get $b = \frac{2}{\surd 3} = 1.154 +$; consequently $d = 20.8$ very nearly, then (from No. 1 Class L), we have

$$925\ bd^2 = 925 \times 1.154 \times 20.8^2 = 461821.$$

For the Open Rectangular Section.

We have $9d^2 = 4800$ (see No. 2 Class R); that is $3d = 4 \surd 3$ and by evolution, and $d = \frac{40 \surd 3}{3}$; then (from equation G), we get

$$91\ d^3 = 91 \times \frac{(40 \surd 3)^3}{3} = 1120826.$$

For the Complete **I** *formed Section.*

We have $9\ bd = 384$ (See No. 3 Class R), now the breadth of the Rectangular Section was found to be 1·154, which, from the assumed proportions of the **I** formed Section is equal to $\frac{3}{8}$ b; consequently $b = 3{\cdot}077$. Let this value of b be substituted in the equation $9\ bd = 384$, and it becomes $27{\cdot}693\ d = 384$; hence, we have $d = 13{\cdot}86$, therefore (by No. 3 Class L) we get

$$726\ bd^2 = 726 \times 3{\cdot}077 \times 13{\cdot}86^2 = 429130.$$

For the open **I** *formed Section.*

We have, $303\ bd = 19200$ (See No. 4, Class R) but $b = 3{\cdot}077$ as found above, consequently, by substitution we have $9{\cdot}323\ d = 19200$, from which we find $d = 20{\cdot}59$, then by (No. 4 Class L) we get

$$686\ bd^2 = 686 \times 3{\cdot}077 \times 20{\cdot}59^2 = 874808.$$

For the Single Flanged or **T** *formed Section.*

We have, $379\ bd = 24000$ (See No. 5, Class R) but b in the Rectangular Section is 1.154; consequently, from the assumed proportions for the **I** formed Section, $b = 4{\cdot}616$; therefore, by substitution, we get $1749.464\ d = 24000$, from which we find $d = 13{\cdot}72$; then (by No. 5, Class L) we get

$$393\ bd^2 = 393 \times 4{\cdot}616 \times 13{\cdot}72^2 = 341405.$$

These numbers when brought together will stand as follows:

For the complete Rectangular Section,	461821
For the open Rectangular Section,	1120826
For the complete **I** formed Section,	429130
For the open **I** formed Section,	874808
For the single flanged or **T** formed Section,	341405

The above numbers have been computed on the supposition that the narrow part of the Section in the last three cases, is the same as the width of the Rectangular Section in the first case; on this supposition the complete **I** formed Section is deficient in strength as compared with the complete rectangular one, but this deficiency arises from the great quantity of area required in the formation of the flanges, and the consequent diminution of depth; the like remark applies to the single flanged or **T** formed Section, but we shall see what will be the result when the several Sections are considered as having the same depth, and that the comparison may be final, we shall take the depth of the open Rectangular Section as the standard, for since the sectional area is constant, the depth of this Section must be constant also, as long as the proportion obtains which we have assigned to it.

The results of the calculation will exhibit the following proportions:

For the complete Rectangular Section,	512687
For the open Rectangular Section,	1120826
For the complete **I** formed Section,	715364
For the open **I** formed Section,	1003808
For the single flanged, or **T** formed Section,	574578

From this comparison, it appears, that when the Sections are all of one depth and one area, that which is simply rectangular is the weakest of all, the open Rectangular Section is the strongest, and next in strength is the open **I** formed Section; of the other two, the complete **I** formed Section has considerably the advantage, and on account of the symmetry of its form, it claims a preference in the details of practical Science.

Of the Construction of Beams.

The foregoing remarks have been devoted to theoretical investigations, and as much has been introduced as is necessary for a knowledge of the constructions next to be considered; the general equations apply to cases where the dimensions are taken according to circumstances, or chosen at random; and the particular ones apply when the proper proportions can be attended to, which in nine cases out of ten is desirable.

Before proceeding to the actual calculation of the parts, it may be proper to remark that where the particular equations are employed, besides the length of bearing, the load to be supported and the constant number, one dimension of the Section must be given before the other becomes assignable, and when the general equations are employed all the parts except one must be given.

There are only two varieties that can occur in the application of the particular equations, and these are

1. When the length of bearing, the load to be supported, and the breadth of the Section are given, to find the depth.

2. When the length of bearing, the load to be supported, and the depth of the Section are given to find the breadth.

The practical Rule for the first variety is as follows:

Rule 1.—Multiply the given load by the given length of bearing; divide the product by the given breadth, and again by the constant number peculiar to the Section, then the Square Root of the last quotient will give the depth required.

The practical rule for the second variety is as follows:

Rule 2.—Multiply the given load by the given length of bearing; divide the product by the square of the given depth, and again by the constant number peculiar to the Section, and the last quotient will be the breadth sought.

The above rules are expressed for arithmetical operation, but since the process is in general facilitated by the application of logarithms, I will in what follows make use of those numbers whenever they are found to answer the purpose without assigning a reason for so doing, simply presuming, that every person who has occasion for calculations of this kind understands the use of those very interesting and important numbers.

The following examples are given for illustration.

Example 1. Required the depth of a Cast Iron Beam of a Rectangular Section, sufficient to sustain a load of nine tons pressing on the middle of its length, the distance between the supports being twenty-eight feet, and the breadth of the Section one inch and a half.

Nine Tons,	20160	pounds,	log	4·304491
Length of bearing,	28	feet,	log	1·447158
Breadth of Section,	15	inch,	ar: co: log	9·823909
Constant,	925		ar: co: log	7·033858
			Square Root,	2)2·609416
Net number,	20·17	inches,	log	1·304708

Hence, a beam 20·17 inches deep, 1½ inches broad and 28 feet long, will bear a load of 9 tons pressing at the middle of its length, but this, be it remembered, is the utmost that it will bear while the elastic force remains unimpaired; now, it is the practice of some eminent Engineers, to prove their beams to twice the load that is to be permanently sustained, in order to guard against accidents and other contingencies; but in doing this, care must be taken to have the beams of such dimensions, as to admit of this double proof within the limit of elasticity, for if they are not, there is a risk of injuring them so much as to give way with the lesser load; the best method of guarding against accidents is as follows: having estimated the load that is to be permanently sustained, double it, and from the double of the permanent load let the depth be computed, and it will come out such as to admit a double proof.

Recurring to the following example, we have

Eighteen tons,	40320 pounds,		log.	4·605521
Length of bearing,	28 feet,		log.	1·447158
Breadth of Section,	1·5 inches,	ar: co:	log.	9·823909
Constant,	925	ar : co :	log.	7·033858
				2)2·910446
Nat. number	28·52 inches,		log.	1·455223

Here then, a beam 28·52 inches deep, 1½ inches broad and 28 feet between the supports, will admit a proof of 18 tons, its own weight included, and it may be permanently loaded with 9 tons pressing at the middle, 18 tons uniformly distributed over its length, or 36 tons if its ends be firmly fixed in a wall, instead of lying loosely on the support.

I may here further remark, that if the breadth will admit of augmentation, the same object may be obtained by calculating the depth as in the first instance and doubling the breadth, but this is not an economical method, for it doubles the quantity of metal and the effect produced by the weight of the beam at the same time.

Example 2. It is required to determine the dimensions of a Cast Iron Beam of the open Rectangular Section capable of bearing a load of 20 tons uniformly distributed over its length; its length of bearing being 32 feet.

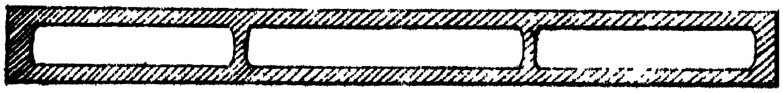
This example may be resolved by equation (G), where it is stated that the breadth of the Section is three twentieths of the whole depth; this being the case, the Rule will be a little varied, as follows:

Rule 3. Multiply the given load by the given length of bearing; divide the product by 91, and extract the cube root of the quotient, for the depth of the Section sought.

20 tons,	44800 pounds,		log.	4·651278
Length of bearing,	32 feet,		log.	1·505150
Constant,	91	ar : co :	log.	8·040202
				3)4·196630
Nat. number,	25·05 inches,		log.	1·398876

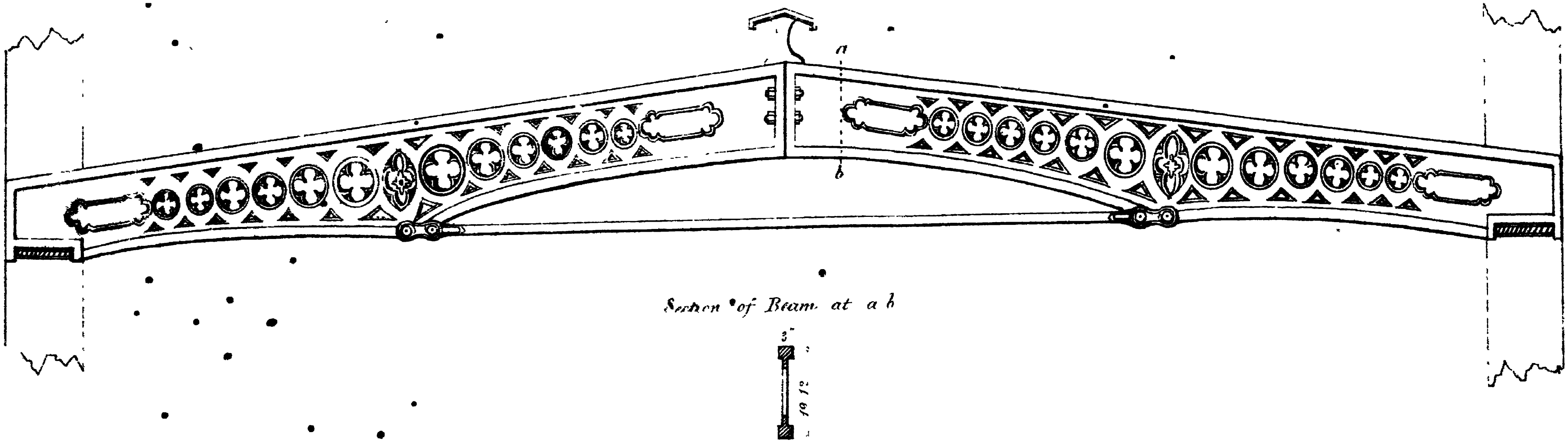
Therefore, 25·05 inches is the whole depth of the Section, and 25·05 × ·7 = 17·535 inches is the depth of the open part; consequently, the breadth is 3·758 inches.

A beam of the dimensions just found will bear permanently a load of 20 tons, and admit a proof of 20 tons at the centre,—it being calculated for a load of that magnitude, and the rule in every case produces the limit of the elastic power. The beam and its Section are below.



Example 3. What must be the depth of a Cast Iron Beam of the open I formed Section, to bear a load of 9 tons at the middle of its length, and admit a central proof of 18 tons; the length of bearing being 22 feet, and the greatest breadth of the Section 3 inches?

Eighteen tons,	40320 pounds,		log.	4·605521
Length of bearing,	22 feet,		log.	1·342423
Breadth of Section,	3 inches,	ar : co :	log.	9·522879
Constant,	686	ar : co	log.	7·163676
				2)2·634499
Nat. number,	20·76 inches,		log.	1·317249

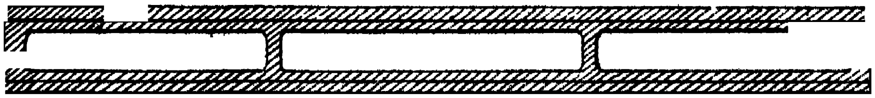


Design for a beam for Transept of S^t Pauls Cathedral Calcutta

H. GOODWYN.

Here then, the whole depth of the Section is 20·76 inches, the depth of the part between the flanges is 20·76 × ·7 = 14·532 inches, and that of the open part is 10·1724 inches; the lesser breadth being 3 × ·375 = 1·125 inches.

A beam of these dimensions will bear permanently a load of 9 tons applied at the middle, and admit a central proof of 18 tons. The beam and its Section are as below:



EXAMPLE 4. What must be the breadth of a Cast Iron Beam of the open **I** formed Section, to bear a load of 12 tons at the middle of its length; the whole depth of the Section being 20 inches and the length of bearing 29 feet?

Depth, ...	20 inches,	.... ar : co : log.	8·698970
			2
			7·397940
Twenty-four tons,.........	53760 pounds,	.... log.	4·730459
Length of bearing,.........	29 feet,	.... log.	1·462398
Constant, ...	686	.... ar : co : log.	7·163676
Nat. number,..............	5·681 inches,	.... log.	0·754473

Here the whole breadth is 5·681 inches, and consequently, the breadth of the middle part is 2·13 inches, the depth of the middle part being 14 inches, and that of the open part 9·8 inches. A beam of these dimensions will bear permanently at the middle of the length, a load of 12 Tons, and admit a central proof 24 tons.

A beam of the open formed Section, of which a sketch is given on the opposite page, for the Transepts of St. Paul's Cathedral in Calcutta, was calculated as follows.

The proportional weight of Roof to be borne by each beam was 16856 lbs., 20,000 lbs. was allowed, and 3 inches assumed as the breadth of flange; the bearing was 28 feet.

Weight or 20,000 lbs.,..	log.	4·301030
Bearing 28 feet,...	log.	1·447158
Breadth of flange 3″.............................. ar: co:	log.	9·522879
Constant No. 686 .... ar: co:	log.	7·163676
Square Root,	2)	2·434743
Nat. number 16·49		1·217371

The whole depth of the beam at the narrow end is therefore 16·49 inches and 16·49 × ·7 = 11·543 depth between flanges 11·543 × ·7 = 8·080 depth of open part, by formula 3 × ·375 = 1·125 breadth of centre part.

The weight of the beam was 2049 lbs.

Pl. 10 Fig. 1 is a Section of the mode adopted by Mr. Cubitt for vaulting the ground floors of the very extensive buildings now erecting at Pimlico; the Iron girders are 11″ deep and 1¼″ thick with a flange 6″, from which the arches spring—the arches are from 7 to 10 feet span with a rise of 10″ a single brick or 9″ thick, the spandrills are filled in with concrete. In the lower floors of some new buildings lately, erected at the "old Jewry," in the City of London, and at the Lunatic Asylum at Hanwell by Mr. Sibley, a similar mode has been adopted ; the girders however differ in form and deserve special notice.

Pl. 10 Fig. 2 shews a Section of the floor of the "old Jewry" buildings, the girder is cast so as to afford springing abutments to the arches, which in this case are only half brick or 4½″ thick. The girders are 9½″ deep at the ends and rise to 14″ in the centre, the thickness of metal above the arch 1¼″ and that of the triangular base ¾″, and at every 2′ 9″ or 3′ 0″ of the length the sloping abutments of the girder are connected below in the casting by a band 4″ wide as shewn in (Figs. 3 and 4). The girders rest on stone corbels in which are notches to receive a tongue (a) cast on the under side at the ends of the girders.

The spans of the arches at the old Jewry are 8 feet with a rise of 12 inches, and those at the Hanwell Asylum 6 feet span.

Pl. 10 Fig. 10 shews a full sized Section of a girder as applied to the above purposes, and attached to it is a scale for different bearings from 20 to 8 feet.

For a 20 feet bearing and from that to 15 feet the depth may be stated at 12″ at the ends, rising to 16″ at the centre, and for bearings from 8 to 12 feet, the depth of 12″ may be uniform throughout, the thickness of metal ¼″, the spread of abutments varying with reference to the rise and span of the arch.

(Pl. 10 Fig. 5.) shews the application of Cast Iron Ribs to the formation of a pointed roof in the Gothic style, the elevation shews two ribs in position, they are united by a Cast Iron Ring in the centre, from which hangs a graceful pendant. Through the centre of the pendant is a Wrought Iron Rod 1″ diameter fixed to the centre of two diagonal bars in the ring, which prevent it from collapsing. A ring at the bottom of the rod may be one of a series for supporting punkahs. The ribs are bolted to the ring thus avoiding almost all lateral pressure. They are inserted in the wall with a spreading base of 16″ wide so that the superstructure and buttresses afford the necessary resistance to any pressure that may arise. The Church of St. Dunstans in London, has been roofed in a somewhat similar way, the building is octagonal, and a rib springs from each angle. At the springings and at the top, are laid chains binding the work together. The roof has a considerable weight to bear in this Church. Correct dimensions of the ribs are given. The lower flanges of the ribs will support brick arches in cement, forming the inner ceiling, and the upper flanges bear the external covering. This form of rib slightly altered in position, and the interior parts connecting the upper and lower flanges traced of Gothic design as shewn in (Pl. 10. Fig. 6.) might be applied to support a roof by bolting the ends of the ribs to a continuous ridge piece and placing purlins in the depth of the upper flange as shewn.

Another mode is shewn in (Fig. 7.) which example is taken from part of the Collegiate Church at Manchester, the building to which such roof is applied should not be very lofty.

I am aware of the difficulty and also of critical observations that may arise with regard to the introduction of Cast Iron into Gothic construction, viz., that the massive appearance of the very beautiful Timber and Stone erections of former times cannot by this means be successfully imitated, and the correctness of the style must be partly deviated from, but the elegant and loftily groined vault is still open to the lovers of the style, (and it has no warmer advocate than the writer of this Memoir,* it is only necessity that compels to a substitution of a material that is indestructible in a country and climate where Timber is subject to such various and rapid modes of decay.

A mode of roofing is shewn in (Pl. 10 Fig. 8) for fire proof purposes, which consists of a light brick arch springing from the cast abutments, laid longitudinally on the wall, the front face bevelled to the form of the spring of the arch.

This abutment is cast hollow, the sides being ¾″ thick, and should be strengthened by a cross rib internally at about every 2½ or 3 feet Wrought Iron Ties of ¾″, or inch diameter—according to the span connect the Iron abutments at the distances of 8 feet throughout, taking the lateral thrust from the walls which can be of ordinary thickness.

Following up this mode an excellent roof might thus be formed, particularly adapted to Conjee Houses, and Jail Cells, but which may also be applied to Magazine Store Rooms and other Buildings, where the space does not exceed 16 or 18 feet.

In the case of Jail and Conjee Houses the arch will spare the interior width of the enclosure, and the Tie Rods should be disposed so as to lie on cross walls or divisions between cells, as in that position they will be protected from injury or mischief (Fig. 9.) The plan will be found very effectual, and at the same time tend to preserve a moderate temperature in buildings which from their small width and low roofs are generally too hot to confine Europeans in with safety or a due regard to health.

H. GOODWYN,
Captain, Engineers.

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* Let it not be imagined that any wish is intended to supercede the correct and most perfectly elegant mode of Roofing a Building of the Gothic Style of Architecture which is by the ribbed and nicely poised pointed Arch, so peculiarly its own, but merely to introduce the means of covering the building should circumstances prohibit the vault being adopted; I hope I may have the opportunity of sketching out the proof of this particular style as being applicable to the Public Buildings of India, with illustrations to the same effect, such is at least my intention.

TABLE 1.

Lengths and Weights of Square Iron from ¼ inch to 5 inches Square from one to eighteen feet.

Size of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15.	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	·208	·416	·624	·833	1·04	1·24	1·45	1·66	1·87	2·08	2·29	2·49	2·7	2·91	3·12	3·33	3·54	3·74
⅜	·468	·937	1·4	1·87	2·34	2·81	3·28	3·75	4·21	4·68	5·15	5·62	6·09	6·56	7·03	7·5	7·96	8·43
½	·833	1·66	2·49	3·33	4·16	4·99	5·83	6·66	7·49	8·33	9·16	9·99	10·83	11·66	12·49	13·33	14·16	14·99
⅝	1·3	2·6	3·9	5·2	6·5	7·8	9·1	10·4	11·7	13·	14·3	15·6	16·9	18·2	19·5	20·8	22·1	23·4
¾	1·87	3·74	5·61	7·48	9·35	11·22	13·09	14·96	16·83	18·7	20·57	22·44	24·31	26·18	28·05	29·92	31·79	33·66
⅞	2·55	5·1	7·65	10·2	12·75	15·3	17·85	20·4	22·95	25·5	28·05	30·6	33·15	35·7	38·25	40·8	43·35	45·9
1	3·33	6·66	9·99	13·32	16·65	19·98	23·31	26·64	29·97	33·3	36·63	39·96	43·29	46·62	49·95	53·28	56·61	59·94
1⅛	4·21	8·42	12·63	16·84	21·05	25·26	29·47	33·68	37·89	42·1	46·31	50·52	54·73	58·94	63·15	67·36	71·57	75 78
1¼	5·2	10·4	15·6	20·8	26·	31·2	36·4	41·6	46·8	52·	57·2	62·4	67·6	72·8	78·	83·2	88·4	93·6
1⅜	6·3	12·6	18·9	25·2	31·5	37·8	44·1	50·4	56·7	63·	69·3	75·6	81·9	88·2	94·5	100·8	107·1	113·4
1½	7·5	15·	22·5	30·	37·5	45·	52·5	60·	67·5	75·	82·5	90·	97·5	105·	112·5	120·	127·5	135·
1⅝	8·8	17·6	26·4	35·2	44·	52·8	61·6	70·4	79·2	88·	96·8	105·6	114·4	123·2	132·	140·8	149·6	158·4
1¾	10·2	20·4	30·6	40·8	51·	61·2	71·4	81·6	91·8	102·	112·2	122·4	132·6	147·8	153·	163·2	173 4	183·6
1⅞	11·71	23·42	35·13	46·84	58·55	70·26	81·97	93·68	105·39	117·1	128·81	140·52	152·23	163·94	175·65	187·36	199·07	210·78
2	13·33	26·66	39·99	53·32	66·65	79·98	93·31	106·64	119·97	133·3	146·63	159·96	173·29	186·62	199·95	213·28	226·61	239·94
2⅛	15·05	30·1	45·15	60·2	75·25	90·3	105·35	120·4	135·45	150·5	165·55	180·6	195·65	210·7	225·75	240·8	255·85	270·9
2¼	16·87	33·74	50·61	67·48	84·35	101·22	118·09	134·96	151·83	168·7	185·57	202·44	219·31	236·18	253·05	269·92	286·79	303·66
2⅜	18·8	37·6	56·4	75·2	94·	112·8	131·6	150·4	169·2	188·	206·8	225·6	244·4	263·2	282·	300·8	319·6	338·4
2½	20·8	41·6	62·4	83·2	104·	124·8	145·6	166·4	187·2	208·	228·8	249·6	270·4	291·2	312·	332·8	353·6	374·4
2⅝	22·96	45·92	68·88	91·84	114·8	137·76	160·72	183·68	206·64	229·6	252·56	275·52	298·48	321·44	344·4	367·36	390·32	413·28
2¾	25·2	50·4	75·6	100·8	126·	151·2	176·4	201·6	226·8	252·	277·2	302·4	327·6	352·8	378·	403·2	428·4	453·6
2⅞	27·55	55·1	82·65	110·2	137·75	165·3	192·85	220·4	247·95	275·5	303·05	330·6	358·15	385·7	413·25	440·8	468·35	495·9
3	30·	60·	90·	120·	150·	180·	210·	240·	270·	300·	330·	360·	390·	420·	450·	480·	510·	540·
3⅛	32·55	65·1	97·65	130·2	162·75	195·3	227·85	260·4	292·95	325·5	358·05	390·6	423·15	455·7	488·25	520·8	553·35	585·9
3¼	35·2	70·4	105·6	140·8	176·	211·2	246·4	281·6	316·8									
3⅜	37·96	75·92	113·88	151·84	189·8	227·76	265·72	303·68	341·64									
3½	40·8	81·6	122·4	163·2	204·	244·8	285·6	326·4	367·2									
3⅝	43·8	87·6	131·4	175·2	219·	262·8	306·6	350·4	394·2									
3¾	46·87	93·74	140·61	187·48	234·35	281·22	328·09	374·96	421·83									
3⅞	50·05	100·1	150·15	200·2	250·25	300·3	350·35	400·4	450·45									
4	53·33	106·66	159·99	213·32	266·65	319·98	373·31	426·64	479·97									
4⅛	56·71	113·42	170·13	226·84	283·55	340·26	396·97	453·68	510·39									
4¼	60·2	120·4	180·6	240·8	301·	361·2	421·4	481·6	541·8									
4⅜	63·8	127·6	191·4	255·2	319·	382·8	446·6	510·4	574·2									
4½	67·5	135·	202·5	270·	337·5	405	472·5	540·	607·5									
4⅝	71·3	142·6	213·9	285·2	356·5	427·8	499·1	570·4	641·7									
4¾	75·2	150·4	225·6	300·8	376·	451·2	526·4	601·6	676·8									
4⅞	79·21	158·42	237·63	316·84	396·05	475·26	554·47	633·68	712·82									
5	83·33	166·66	249·99	333·32	416·65	499·98	583·31	666·64	749·97									

TABLE 2.

Lengths and Weights of Round Iron from ¼ inch to 5 inches diam. from one to eighteen feet.

Size of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	·163	·327	·49	·654	·818	·981	1·14	1·3	1·47	1·63	1·79	1·96	2·12	2·29	2·45	2·61	2·78	2·94
⅜	·368	·736	1·1	1·47	1·84	2·2	2·57	2·94	3·31	3·68	4·04	4·41	4·78	5·15	5·52	5·89	6·25	6·62
½	·654	1·3	1·96	2·61	3·27	3·92	4·58	5·23	5·89	6·54	7·19	7·85	8·5	9·16	9·81	10·47	11·12	11·78
⅝	1·02	2·04	3·06	4·08	5·1	6·12	7·14	8·16	9·18	10·2	11·22	12·24	13·26	14·28	15·3	16·32	17·34	18·36
¾	1·47	2·94	4·41	5·88	7·35	8·82	10·29	11·76	13·23	14·7	16·17	17·64	19·11	20·58	22·05	23·52	24·99	26·46
⅞	2·	4·	6·	8·	10·	12·	14·	16·	18·	20·	22·	24·	26·	28·	30·	32·	34·	36·
1	2·61	5·22	7·83	10·44	13·05	15·66	18·27	20·88	23·49	26·1	28·71	31·32	33·93	36·54	39·15	41·76	44·37	46·98
1⅛	3·31	6·62	9·93	13·24	16·55	19·86	23·17	26·48	29·79	33·1	36·41	39·72	43·03	46·34	49·65	52·96	56·27	59·58
1¼	4·09	8·18	12·27	16·36	20·45	24·54	28·63	32·72	36·81	40·9	44·99	49·08	53·17	57·26	61·35	65·44	69·53	73·62
1⅜	4·94	9·88	14·82	19·76	24·7	29·64	34·58	39·52	44·46	49·4	54·34	59·28	64·22	69·16	74·1	79·04	83·98	88·92
1½	5·89	11·78	17·67	23·56	29·45	35·34	41·23	47·12	53·01	58·9	64·79	70·68	76·57	82·46	88·35	94·24	100·13	106·02
1⅝	6·91	13·82	20·73	27·64	34·55	41·46	48·37	55·28	62·19	69·1	76·01	82·92	89·83	96·74	103·65	110·56	117·47	124·38
1¾	8·01	16·02	24·03	32·04	40·05	48·06	56·07	64·08	72·09	80·1	88·11	96·12	104·13	112·14	120·15	128·16	136·17	144·18
1⅞	9·2	18·4	27·6	36·8	46·	55·2	64·4	73·6	82·8	92·	101·2	110·4	119·6	128·8	138·	147·2	156·4	165·6
2	10·47	20·94	31·41	41·88	52·35	62·82	73·29	83·76	94·23	104·7	115·17	125·64	136·11	146·58	157·05	167·52	177·99	188·46
2⅛	11·82	23·64	35·46	47·28	59·1	70·92	82·74	94·56	106·38	118·2	130·02	141·84	153·66	165·48	177·3	189·12	200·94	212·76
2¼	13·25	26·5	39·75	53·	66·25	79·5	92·75	106·	119·25	132·5	145·75	159·	172·25	185·5	198·75	212·	225·25	238·5
2⅜	14·76	29·52	44·28	59·04	73·8	88·56	103·32	118·08	132·84	147·6	162·36	177·12	191·88	206·64	221·4	236·16	250·92	265·68
2½	16·36	32·72	49·08	65·44	81·8	98·16	114·52	130·88	147·24	163·6	179·96	196·32	212·68	229·04	245·4	261·76	278·12	294·48
2⅝	18·03	36·06	54·09	72·12	90·15	108·18	126·21	144·24	162·27	180·3	198·33	216·36	234·39	252·42	270·45	288·48	306·51	324·54
2¾	19·79	39·58	59·37	79·16	98·95	118·74	138·53	158·32	178·11	197·9	217·69	237·48	257·27	277·06	296·85	316·64	336·43	356·22
2⅞	21·63	43·26	64·89	86·52	108·15	129·78	151·41	173·04	194·67	216·3	237·93	259·56	281·19	302·82	324·45	346·08	367·71	389·34
3	23·56	47·12	70·68	94·24	117·8	141·36	164·92	188·48	212·04	235·6	259·16	282·72	306·28	329·84	353·4	376·96	400·52	424·08
3⅛	25·56	51·12	76·68	102·24	127·8	153·36	178·92	204·48	230·04	255·6	281·16	306·72	332·28	357·84	383·4	408·96	434·52	460·08
3¼	27·65	55·3	82·95	110·6	138·25	165·9	193·55	221·2	248·85									
3⅜	29·82	59·64	89·46	119·28	149·1	178·92	208·74	238·56	268·38									
3½	32·07	64·14	96·21	128·28	160·35	192·42	224·49	256·56	288·63									
3⅝	34·4	68·8	103·2	137·6	172·	206·4	240·8	275·2	309·6									
3¾	36·81	73·62	110·43	147·24	184·05	220·86	257·67	294·48	331·29									
3⅞	39·31	78·62	117·93	157·24	196·55	235·86	275·17	314·48	353·79									
4	41·88	83·76	125·64	167·52	209·4	251·28	293·16	335·04	376·92									
4⅛	44·54	89·08	133·62	178·16	222·7	267·24	311·78	356·32	400·86									
4¼	47·28	94·56	141·84	189·12	236·4	283·68	330·96	378·24	425·52									
4⅜	50·11	100·22	150·33	200·44	250·55	300·66	350·77	400·88	450·99									
4½	53·01	106·02	159·03	212·04	265·05	318·06	371·07	424·08	477·09									
4⅝	56·	112·	168·	224·	280·	336·	392·	448·	504·									
4¾	59·06	118·12	177·18	236·24	295·3	354·36	413·42	472·48	531·54									
4⅞	62·21	124·42	186·63	248·84	311·05	373·26	435·47	497·68	559·89									
5	65.45	130.9	196.35	261·8	327·25	392·7	458·15	523·6	589·05									

TABLE 3.

Lengths and Weights of Flat Iron from ¼ inch to 1 inch thick from one foot to eighteen feet.

Width of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15.	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs·
1	·83	1·66	2·49	3·32	4·15	4·98	5·81	6·64	7·47	8·3	9·13	9·96	10·79	11·62	12·45	13·28	14·11	14·94
1⅛	·93	1·86	2·79	3·72	4·15	5·58	6·51	7·44	8·37	9·3	10·23	11·16	12·09	13·02	13·95	14·88	15·81	16·74
1¼	1·04	2·08	3·12	4·16	5·2	6·24	7·28	8·32	9·36	10·4	11·44	12·48	13·52	14·56	15·6	16·64	17·68	18·72
1⅜	1·14	2·28	3·42	4·56	5·7	6·84	7·98	9·12	10·26	11·4	12·54	13·68	14·82	15·96	17·1	18·24	19·38	20·52
1½	1·25	2·5	3·75	5·	6·25	7·5	8·75	10·	11·25	12·5	13·75	15·	16·25	17·5	18·75	20·	21·25	22·5
1¾	1·45	2·9	4·35	5·8	7·25	8·7	10·15	11·6	13·05	14·5	15·95	17·4	18·85	20·3	21·75	23·2	24·65	26·1
2	1·66	3·32	4·98	6·64	8·3	9·96	11·62	13·28	14·94	16·6	18·26	19·92	21·58	23·24	24·9	26·56	28·22	29·88
2¼	1·87	3·74	5·61	7·48	9·35	11·22	13·09	14·96	16·83	18·7	20·57	22·44	24·31	26·18	28·05	29·92	31·79	33·66
2½	2·08	4·16	6·24	8·32	10·4	12·48	14·56	16·64	18·72	20·8	22·88	24·96	27·04	29·12	31·2	33·28	35·36	37·44
2¾	2·29	4·58	6·87	9·16	11·45	13·74	16·03	18·32	20·61	22·9	25·19	27·48	29·77	32·06	34·35	36·64	38·93	41·22
3	2·5	5·	7·5	10·	12·5	15·	17·5	20·	22·5	25·	27·5	30·	32·5	35·	37·5	40·	42·5	45·
3¼	2·7	5·4	8·1	10·8	13·5	16·2	18·9	21·6	24·3	27·	29·7	32·4	35·1	37·8	40·5	43·2	45·9	48·6
3½	2·91	5·82	8·73	11·64	14·55	17·46	20·37	23·28	26·19									
3¾	3·11	6·22	9·33	12·44	15·55	18·66	21·77	24·88	27·99									
4	3·33	6·66	9·99	13·32	16·65	19 98	23·31	26·64	29·97									
4¼	3·53	7·06	10·59	14·12	17·65	21·18	24·71	28·24	31·77									
4½	3·74	7·48	11·22	14·96	18·7	22·44	26·18	29·92	33·66									
4¾	3·95	7·9	11·85	15·8	19·75	23·7	27·65	31·6	35·55									
5	4·16	8·32	12·48	16·64	20·8	24·96	29·12	33·28	37·44									
5¼	4·37	8·74	13·11	17·48	21·85	26·22	30·59	34·96	39·33									
5½	4·58	9·16	13·74	18·32	22·9	27·48	32·06	36·64	41·22									
5¾	4·79	9·58	14·37	19·16	23·95	28·74	33·53	38·32	43·11									
6	5·	10·	15·	20·	25·	30·	35·	40·	45·									
6¼	5·2	10·4	15·6	20·8	26·	31·2	36·4	41·6	46·8									

TABLE 4.

Lengths and Weights of Flat Iron ⅜ inch thick from one foot to eighteen feet.

Width of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15.	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	1·25	2·5	3·75	5·	6·25	7·5	8·75	10·	11·25	12·5	13·75	15·	16·25	17·5	18·75	20·	21·25	22·5
1⅛	1·4	2·8	4·2	5·6	7·	8·4	9·8	11·2	12·6	14·	15·4	16·8	18·2	19·6	21·	22·4	23·8	25·2
1¼	1·56	3·12	4·68	6·24	7·8	9·36	10·92	12·48	14·04	15·6	17·16	18·72	20·28	21·84	23·4	24·96	26·52	28·08
1⅜	1·71	3·42	5·13	6·84	8·55	10·26	11·97	13·68	15·39	17·1	18·81	20·52	22·23	23·94	25·65	27·36	29·07	30·78
1½	1·87	3·74	5·61	7·48	9·35	11·22	13·09	14·96	16·83	18·7	20·57	22·44	24·31	26·18	28·05	29·92	31·79	33·66
1¾	2·18	4·36	6·54	8·72	10·9	13·08	15·26	17·44	19·62	21·8	23·98	26·16	28·34	30·52	32·7	34·88	37·06	39·24
2	2·5	5·	7·5	10·	12·5	15·	17·5	20·	22·5	25·	27·5	30·	32·5	35·	37·5	40·	42·5	45·
2¼	2·81	5·62	8·43	11·24	14·05	16·86	19·67	22·48	25·29	28·1	30·91	33·72	36·53	39·34	42·15	44·96	47·77	50·58
2½	3·12	6·24	9·36	12·48	15·6	18·72	21·84	24·96	28·08	31·2	34·32	37·44	40·56	43·68	46·8	49·92	53·04	56·16
2¾	3·43	6·86	10·29	13·72	17·15	20·58	24·01	27·44	30·87	34·3	37·73	41·16	44·59	48·02	51·45	54·88	58·31	61·74
3	3·75	7·5	11·25	15·	18·75	22·5	26·25	30·	33·75	37·5	41·25	45·	48·75	52·5	56·25	60·	63·75	67·5
3¼	4·06	8·12	12·18	16·24	20·3	24·36	28·42	32·48	36·54	40·6	44·66	48·72	52·78	56·84	60·9	64·96	69·02	73·08
3½	4·37	8·74	13·11	17·48	21·85	26·22	30·59	34·96	39·33									
3¾	4·68	9·36	14·94	18·72	23·4	28·08	32·76	37·44	42·12									
4	5·	10·	15·	20·	25·	30·	35·	40·	45·									
4¼	5·31	10·62	15·93	21·24	26·55	31·86	37·17	42·48	47·79									
4½	5·62	11·24	16·86	22·48	28·1	33·72	39·34	44·96	50·58									
4¾	5·93	11·86	17·79	23·72	29·65	35·58	41·51	47·44	53·37									
5	6·25	12·5	18·75	25·	31·25	37·5	43·75	50·	56·25									
5¼	6·55	13·1	19·65	26·2	32·75	39·3	45·85	52·4	58·95									
5½	6·86	13·72	20·58	27·44	34·3	41·16	48·02	54·88	61·74									
5¾	7·18	14·36	21·54	28·72	35·9	43·08	50·26	57·44	64·62									
6	7·5	15·	22·5	30·	37·5	45·	52·5	60·	67·5									
6¼	7·81	15·62	23·43	31·24	39·05	46·86	54·67	62·48	70·29									

TABLE 5.

Lengths and Weights of Flat Iron ½ inch thick from one foot to eighteen feet.

Width of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15.	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	1·66	3·32	4·98	6·64	8·3	9·96	11·62	13·28	14·94	16·6	18·26	19·92	21·58	23·24	24·9	26·56	28·22	29·88
1⅛	1·87	3·74	5·61	7·48	9·35	11·22	13·09	14·96	16·83	18·7	20·57	22·44	24·31	26·18	28·05	29·92	31·79	33·66
1¼	2·08	4·16	6·24	8·32	10·4	12·48	14·56	16·64	18·72	20·8	22·88	24·96	27·04	29·12	31·2	33·28	35·36	37·44
1⅜	2·29	4·58	6·87	9·16	11·45	13·74	16·03	18·32	20·61	22·9	25·19	27·48	29·77	32·06	34·35	36·64	38·93	41·22
1½	2·5	5·	7·5	10·	12·5	15·	17·5	20·	22·5	25·	27·5	30·	32·5	35·	37·5	40·	42·5	45·
1¾	2·91	5·82	8·73	11·64	14·55	17·46	20·37	23·28	26·19	29·1	32·01	34·92	37·83	40·74	43·65	46·56	49·47	52·38
2	3·33	6·66	9·99	13·32	16·65	19·98	23·31	26·64	29·97	33·3	36·63	39·96	43·29	46·62	49·95	53·28	56·61	59·94
2¼	3·75	7·5	11·25	15·	18·75	22·5	26·25	30·	33·75	37·5	41·25	45·	48·75	52·5	56·25	60·	63·75	67·5
2½	4·16	8·32	12·48	16·64	20·8	24·96	29·12	33·28	37·44	41·6	45·76	49·92	54·08	58·24	62·4	66·56	70·72	74·88
2¾	4·58	9·16	13·74	18·32	22·9	27·48	32·06	36·64	41·22	45·8	50·38	54·96	59·54	64·12	68·7	73·28	77·86	82·44
3	5·	10·	15·	20·	25·	30·	35·	40·	45·	50·	55·	60·	65·	70·	75·	80·	85·	90·
3¼	5·41	10·82	16·23	21·64	27·05	32·46	37·87	43·28	48·69	54·1	59·51	64·92	70·33	75·74	81·15	86·56	91·97	97·38
3½	5·83	11·66	17·49	23·32	29·15	34·98	40·81	46·64	52·47									
3¾	6·25	12·5	18·75	25·	31·25	37·5	43·75	50·	56·25									
4	6·66	13·32	19·98	26·64	33·3	39·96	46·62	53·28	59·94									
4¼	7·08	14·16	21·24	28·32	35·4	42·48	49·56	56·64	63·72									
4½	7·5	15·	22·5	30·	37·5	45·	52·5	60·	67·5									
4¾	7·91	15·82	23·73	31·64	39·55	47·42	55·37	63·28	71·19									
5	8·32	16·64	24·96	33·28	41·6	49·96	58·24	66·56	74·88									
5¼	8·75	17·5	26·25	35·	43·75	52·5	61·25	70·	78·75									
5½	9·16	18·32	27·48	36·64	45·8	54·96	64·12	73·28	82·44									
5¾	9·58	19·16	28·74	38·32	47·9	57·48	67·06	76·64	86·22									
6	10·	20·	30·	40·	50·	60·	70·	80·	90·									
6¼	10·41	20·82	31·23	41·64	52·05	62·46	72·87	83·28	93·69									

TABLE 6.

Lengths and Weights of Flat Iron ⅝ inch thick from one foot to eighteen feet.

Width of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15.	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	2·08	4·16	6·24	8·32	10·4	12·48	14·56	16·64	18·72	20·8	22·88	24·96	27·04	29·12	31·2	33·28	35·36	37·44
1⅛	2·34	4·68	7·02	9·36	11·7	14·04	16·38	18·72	21·06	23·4	25·74	28·08	30·42	32·76	35·1	37·44	39·78	42·12
1¼	2·6	5·2	7·8	10·4	13·	15·6	18·2	20·8	23·4	26·	28·6	31·2	33·8	36·4	39·	41·6	44·2	46·8
1⅜	2·86	5·72	8·58	11·44	14·3	17·16	20·02	22·88	25·74	28·6	31·46	34·32	37·18	40·04	42·9	45·76	48·62	51·48
1½	3·12	6·24	9·36	12·48	15·6	18·72	21·84	24·96	28·08	31·2	34·32	37·44	40·56	43·68	46·8	49·92	53·04	56·16
1¾	3·64	7·28	10·92	14·56	18·2	21·84	25·48	29·12	32·76	36·4	40·04	43·68	47·32	50·96	54·6	58·24	61·88	65·52
2	4·16	8·32	12·48	16·64	20·8	24·96	29·12	33·28	37·44	41·6	45·76	49·92	54·08	58·24	62·4	66·56	70·72	74·88
2¼	4·68	9·36	14·04	18·72	23·4	28·08	32·76	37·44	42·12	46·8	51·48	56·16	60·84	65·52	70·2	74·88	79·56	84·24
2½	5·2	10·4	15·6	20·8	26·	31·2	36·4	41·6	46·8	52·	57·2	62·4	67·6	72·8	78·	83·2	88·4	93·6
2¾	5·72	11·44	17·16	22·88	28·6	34·32	40·04	45·76	51·48	57·2	62·92	68·64	74·36	80·08	85·8	91·52	97·24	102·96
3	6·25	12·5	18·75	25·	31·25	37·5	43·75	50·	56·25	62·5	68·75	75·	81·25	87·5	93·75	100·	106·25	112·5
3¼	6·77	13·54	20·31	27·08	33·85	40·62	47·39	54·16	60·93	67·7	74·47	81·24	88·01	94·78	101·55	108·32	115·09	121·86
3½	7·29	14·58	21·87	29·16	36·45	43·74	51·03	58·32	65·61									
3¾	7·8	15·6	23·4	31·2	39·	46·8	54·6	62·4	70·2									
4	8·32	16·64	24·96	33·28	41·6	49·92	58·24	66·56	74·88									
4¼	8·85	17·7	26·55	35·4	44·25	53·1	61·95	70·8	79·65									
4½	9·36	18·72	28·08	37·44	46·8	56·16	65·52	74·88	84·24									
4¾	9·88	19·76	29·64	39·52	49·4	59·28	69·16	79·04	88·92									
5	10·4	20·8	31·2	41·6	52·	62·4	72·8	83·2	93·6									
5¼	10·92	21·84	32·76	43·68	54·6	65·52	76·44	87·36	98·28									
5½	11·45	22·9	34·35	45·8	57·25	68·7	80·15	91·6	103·05									
5¾	11·97	23·94	35·91	47·88	59·85	71·82	83·79	95·76	107·73									
6	12·5	25·	37·5	50·	62·5	75·	87·5	100·	112·5									
6¼	13·02	26·04	39·06	52·08	65·1	78·12	91·14	104·16	117·18									

TABLE 7.

Lengths and Weights of Flat Iron ¾ inch thick from one foot to eighteen feet.

Width of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15.	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	2·5	5·	7·5	10·	12·5	15·	17·5	20·	22·5	25·	27·5	30·	32·5	35·	37·5	40·	42·5	45·
1⅛	2·81	5·62	8·43	11·24	14·05	16·86	19·67	22·48	25·29	28·1	30·91	33·72	36·53	39·34	42·15	44·96	47·77	50·58
1¼	3·12	6·24	9·36	12·48	15·6	18·72	21·84	24·96	28·08	31·2	34·32	37·44	40·56	43·68	46·8	49·92	53·04	56·16
1⅜	3·4	6·8	10·2	13·6	17·	20·4	23·8	27·2	30·6	34·	37·4	40·8	44·2	47·6	51·	54·4	57·8	61·2
1½	3·75	7·5	11·25	15·	18·75	22·5	26·25	30·	33·75	37·5	41·25	45·	48·75	52·5	56·25	60·	63·75	67·5
1¾	4·37	8·74	13·11	17·48	21·85	26·22	30·59	34·96	39·33	43·7	48·07	52·44	56·81	61·18	65·55	69·92	74·29	78·66
2	5·	10·	15·	20·	25·	30·	35·	40·	45·	50·	55·	60·	65·	70·	75·	80·	85·	90·
2¼	5·62	11·24	16·86	22·48	28·1	33·72	39·34	44·96	50·58	56·2	61·82	67·44	73·06	78·68	84·3	89·92	95·54	101·16
2½	6·25	12·5	18·75	25·	31·25	37·5	43·75	50·	56·25	62·5	68·75	75·	81·25	87·5	93·75	100·	106·25	112·5
2¾	6·87	13·74	20·61	27·48	34·35	41·22	48·09	54·96	61·83	68·7	75·57	82·44	89·31	96·18	103·05	109·92	116·79	123·66
3	7·5	15·	22·5	30·	37·5	45·	52·5	60·	67·5	75·	82·5	90·	97·5	105·	112·5	120·	127·5	135·
3¼	8·12	16·24	24·36	32·48	40·6	48·72	56·84	64·96	73·08	81·2	89·32	97·44	105·56	113·68	121·8	129·92	138·04	146·16
3½	8·75	17·5	26·25	35·	43·75	52·5	61·25	70·	78·75									
3¾	9·37	18·74	28·11	37·48	46·85	56·22	65·59	74·96	84·33									
4	10·	20·	30·	40·	50·	60·	70·	80·	90·									
4¼	10·62	21·24	31·86	42·48	53·1	63·72	74·34	84·96	95·58									
4½	11·25	22·5	33·75	45·	56·25	67·5	78·75	90·	101·25									
4¾	11·87	23·74	35·61	47·48	59·35	71·22	83·09	94·96	106·83									
5	12·5	25·	37·5	50·	62·5	75·	87·5	100·	112·5									
5¼	13·12	26·24	39·36	52·48	65·6	78·72	91·84	104·96	118·08									
5½	13·75	27·5	41·25	55·	68·75	82·5	96·25	110·	123·75									
5¾	14·37	28·74	43·11	57·48	71·85	86·22	100·59	114·96	129·33									
6	15·	30·	45·	60·	75·	90·	105·	120·	135·									
6¼	15·62	31·24	46·86	62·48	78·1	93·72	109·34	124·96	140·58									

TABLE 8.

Lengths and Weights of Flat Iron ⅞ inch thick from one foot to eighteen feet.

Width of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15.	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	2.91	5·82	8·73	11·64	14·55	17·46	20·37	23·28	26·19	29·1	32·01	34·92	37·83	40·74	43·65	46·56	49·47	52·38
1⅛	3·28	6·56	9·84	13·12	16·4	19·68	22·96	26·24	29·52	32·8	36·08	39·36	42·64	45·92	49·2	52·48	55·76	59·04
1¼	3·64	7·28	10·92	14·56	18·2	21·84	25·48	29 12	32·76	36·4	40·04	43·68	47·32	50·96	54·6	58·24	61·88	65·52
1⅜	4·01	8·02	12·03	16·04	20·05	24·06	28·07	32·08	36·09	40 1	44·11	48·12	52·13	56·14	60·15	64·16	68·17	72·18
1½	4·37	8·74	13·11	17·48	21·85	26·22	30·59	34·96	39·33	43 7	48·07	52·44	56·81	61·18	65·55	69·92	74·29	78·66
1¾	5·1	10·2	15·3	20·4	25·5	30·6	35·7	40·8	45·9	51·	56·1	61·2	66·3	71·4	76·5	81·6	86·7	91·8
2	5·83	11·66	17·49	23·32	29·15	34·98	40·81	46·64	52·47	58·3	64·13	69·96	75·79	81·62	87·45	93·28	99·11	104·94
2¼	6·56	13·12	19·68	26·24	32·8	39·36	45·92	52·48	59·04	65·6	72·16	78·72	85·28	91·84	98·4	104·96	111·52	118·08
2½	7·29	14·58	21·87	29·16	36·45	43·74	51·03	58·32	65·61	72·9	80·19	87·48	94·77	102·06	109·35	116·64	123·93	131·22
2¾	8·02	16·04	24·06	32·08	40·1	48·12	56·14	64·16	72·18	80·2	88·22	96·24	104·26	112·28	120·3	128·32	136·34	144·36
3	8·75	17·5	26 25	35·	43·75	52·5	61·25	70·	78·75	87·5	96·25	105.	113·75	122·5	131·25	140·	148·75	157·5
3¼	9·47	18·94	28·41	37·88	47·35	56·82	66·29	75·76	85·23	94·7	104·17	113·64	123·11	132·58	142·05	151·52	160·99	170·46
3½	10·2	20·4	30·6	40·8	51·	61·2	71·4	81·6	91·8									
3¾	10·93	21·86	32·79	43·72	54·65	65·58	76·51	87·44	98·37									
4	11·66	23·32	34·98	46·64	58·3	69·96	81·62	93·28	104·94									
4¼	12·39	24·78	37·17	49·56	61·95	74·34	86·73	99·12	111·51									
4½	13·12	26·24	39·36	52·48	65·6	78·72	91·84	104·96	118·08									
4¾	13·85	27·7	41·55	55·4	69·25	83·1	96·95	110·8	124·65									
5	14·58	29·16	43·74	58·32	72·9	87·48	102·06	116·64	131·22									
5¼	15·31	30·62	45·93	61·24	76·55	91·86	107·17	122·48	137·79									
5½	16·04	32·08	48·12	64·16	80·2	96·24	112·28	128 32	144·36									
5¾	16·77	33·54	50·31	67·08	83 85	100·62	117·39	134·16	150·93									
6	17·5	35·	52·5	70·	87·5	105·	122·5	140·	157·5									
6¼	18·22	36·44	54·66	72·88	91·1	109·32	127·54	145·76	163·96									

TABLE 9.

Lengths and Weights of Flat Iron 1 *inch thick from* 1 *foot to* 18 *feet.*

Width of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7	Feet 8.	Feet 9.	Feet 10.	Feet 11.	Feet 12.	Feet 13.	Feet 14.	Feet 15.	Feet 16.	Feet 17.	Feet 18.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1⅛	3·75	7·5	11·25	15·	18·75	22·5	26·25	30·	33·75	37·5	41·25	45·	48·75	52·5	56·25	60·	63·75	67·5
1¼	4·16	8·32	12·48	16·64	20·8	24·96	29·12	33·28	37·44	41·6	45·76	49·92	54·08	58·24	62·4	66·56	70·72	74·88
1⅜	4·58	9·16	13·74	18·32	22·9	27·48	32·06	36·64	41·22	45·8	50·38	54·96	59·54	64·12	68·7	73·28	77·86	82·44
1½	5·	10·	15·	20·	25·	30·	35·	40·	45·	50·	55·	60·	65·	70·	75·	80·	85·	90·
1¾	5·83	11·66	17·49	23·32	29·15	34·98	40·81	46·64	52·47	58·3	64·13	69·96	75·79	81·62	87·45	93·28	99·11	104·94
2	6·66	13·32	19·98	26·64	33·3	39·96	46·64	53·28	59·94	66·6	73·26	79·92	86·58	93·24	99·9	106·56	113·22	119·88
2¼	7·5	15·	22·5	30·	37·5	45·	52·5	60·	67·5	75·	82·5	90·	97·5	105·	112·5	120·	127·5	135·
2½	8·33	16·66	24·99	33·32	41·65	49·98	58·31	66·64	74·97	83·3	91·63	99·96	108·29	116·62	124·95	133·28	141·61	149·94
2¾	9·16	18·32	27·48	36·64	45·8	54·96	64·12	73·28	82·44	91·6	100·76	109·92	119·08	128·24	137·4	146·56	155·72	164·88
3	10·	20·	30·	40·	50·	60·	70·	80·	90·	100·	110·	120·	130·	140·	150·	160·	170·	180·
3¼	10·83	21·66	32·49	43·32	54·15	64·98	75·81	86·64	97·47	108·3	119·13	129·96	140·79	151·62	162·45	173·28	184·11	194·94
3½	11·66	23·32	34·98	46·64	58·3	69·96	81·62	93·28	104·94	116·6	128·26	139·92	151·58	163·24	174·9	186·56	198·22	209·88
3¾	12·5	25·	37·5	50·	62·5	75·	87·5	100·	112·5									
4	13·33	26·66	39·99	53·32	66·65	79·98	93·31	106·64	119·97									
4¼	14·16	28·32	42·48	56·64	70·8	84·96	99·12	113·28	127·44									
4½	15·	30·	45·	60·	75·	90·	105·	120·	135·									
4¾	15·83	31·66	47·49	63·32	79·15	94·98	110·81	126·64	142·47									
5	16·66	33·32	49·98	66·64	83·3	99·96	116·62	133·28	149·94									
5¼	17·49	34·98	52·47	69·96	87·45	104·94	122·43	139·92	157·41									
5½	18·32	36·64	54·96	73·28	91·6	109·92	128·24	146·56	164·88									
5¾	19·16	38·32	57·48	76·64	95·8	114·96	134·12	153·28	172·44									
6	20·	40·	60·	80·	100·	120·	140·	160·	180·									
6¼	20·83	41·66	62·49	83·32	104·15	124·98	145·81	166·64	187·47									
6½	21·66	43·32	64·98	86·64	108·3	129·96	151·62	173·28	194·94									

TABLE 10.

Weight of a superficial foot of Sheet Iron as per Birmingham Wire Gauge.

Nos. of Gauge, ...	1.	2.	3.	4.	5.	6.	7.
Weight, ...	lbs. 12·55	lbs. 11·25	lbs. 10·45	lbs. 9·55	lbs. 8·66	lbs. 8·34	lbs. 7·5
Nos. of Gauge, ...	8.	9.	10.	11.	12.	13.	14.
Weight, ...	6·64	6·29	5·5	4·73	4·3	3·64	3·23

Nos. of Gauge, ...	15.	16.	17.	18.	19.	20.
Weight, ...	lbs. 2·97	lbs. 2·62	lbs. 2·19	lbs. 1·97	lbs. 1·7	lbs. 1·41
Nos. of Gauge, ...	21.	22.	23.	24.	25.	26.
Weight, ...	1·32	1·15	·99	·95	·84	·78

TABLE 11.

Lengths and Weights of Square Iron.

Size of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	·208	·416	·624	·833	1·04	1·24	1·45	1·66	1·87	2.08
⅜	·468	·937	1·4	1·87	2·34	2·81	3·28	3·75	4·21	4.68
½	·833	1·66	2·49	3·33	4·16	4·99	5·83	6·66	7·49	8·33
⅝	1·3	2·6	3·9	5·2	6·5	7·8	9·1	10·4	11·7	13·
¾	1·87	3·74	5·61	7·48	9·35	11·22	13·09	14·96	16·83	18·7
⅞	2·55	5·1	7·65	10·2	12·75	15·3	17·85	20·4	22·95	25·5
1	3·33	6·66	9·99	13·32	16·65	19·98	23·31	26·64	29·97	33·3
1⅛	4·21	8·42	12·63	16·84	21·05	25·26	29·47	33·68	37·89	42·1
1¼	5·2	10·4	15·6	20·8	26·	31·2	36·4	41·6	46·8	52·
1⅜	6·3	12·6	18·9	25·2	31·5	37·8	44·1	50·4	56·7	63·
1½	7·5	15·	22·5	30·	37·5	45·	52·5	60·	67·5	75.
1⅝	8·8	17·6	26·4	35·2	44·	52·8	61·6	70·4	79·2	88·
1¾	10·2	20·4	30·6	40·8	51·	61·2	71·4	81·6	91·8	102·
1⅞	11·71	23·42	36·13	46·84	58·55	70·26	81·97	93·68	105·39	117·1
2	13·33	26·66	39·99	53·32	66·65	79·98	93·31	106·64	119·97	133·3
2⅛	15·05	30·1	45·15	60·2	75·25	90·3	105·35	120·4	135·45	150·5
2¼	16·87	33·74	50·61	67·48	84·35	101·22	118·09	134·96	151·83	168·7
2⅜	18·8	37·6	56·4	75·2	94·	112·8	131·6	150·4	169·2	188·
2½	20·8	41·6	62·4	83·2	104·	124·8	145·6	166·4	187·2	208·
2⅝	22·96	45·92	68·88	91·84	114·8	137·76	160·72	183·68	206·64	292·6
2¾	25·2	50·4	75·6	100·8	126·	151·2	176·4	201·6	226·8	252·
2⅞	27·55	55·1	82·65	110·2	137·75	165·8	192·85	220·4	247·95	275·5
3	30·	60·	90·	120·	150·	180·	210·	240·	270·	300·
3⅛	32·55	65·1	97·65	130·2	162·75	195·3	227·85	260·4	292·95	325·5
3¼	35·2	70·4	105·6	140·8	176·	211·2	246·4	281·6	316·8	
3⅜	37·96	75·92	113·88	151·84	189·8	227·76	265·72	303·68	341·64	
3½	40·8	81·6	122·4	163·2	204·	244·8	285·6	326·4	367·2	
3⅝	43·8	87·6	131·4	175·2	219·	262·8	306·6	350·4	394·2	
3¾	46·87	93·74	140·61	187·48	234·35	281·22	328·09	374·96	421.83	
3⅞	50·05	100·1	150·15	200·2	250·25	300·3	350·35	400·4	450·45	
4	53·33	101·66	159·99	213·32	266·65	319·98	373·31	426·64	479·97	
4⅛	56·71	113·42	170·13	226·84	283·55	340·26	396·97	453·68	510·39	
4¼	60·2	120·4	180·6	240·8	301·	361·2	421·4	481·6	541·8	
4⅜	63·8	127·6	191·4	255·2	319·	382·8	446·6	510·4	574·2	
4½	67·5	135·	202·5	270·	337·5	405·	472·5	540·	607·5	
4⅝	71·3	142·6	213·9	285·2	356·5	427·8	499·1	570·4	641·7	
4¾	75·2	150·4	225·6	300·8	376·	451·2	526·4	601·6	676·8	
4⅞	79·21	158·42	237·63	316·84	396·05	475·26	554·47	633·68	712·82	
5	83·33	166·66	249·99	333·32	416·65	499·98	583·31	666·64	749·97	

TABLE 12.

Lengths and Weights of Round Iron.

Size of Iron.	Feet 1.	Feet 2.	Feet 3.	Feet 4.	Feet 5.	Feet 6.	Feet 7.	Feet 8.	Feet 9.	Feet 10.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	·163	·327	·49	·654	·818	·981	1·14	1·3	1·47	1·63
⅜	·368	·736	1·1	1·47	1·84	2·2	2·57	2·94	3·31	3·68
½	·654	1·3	1·96	2·61	3·27	3·92	4·58	5·23	5·89	6·54
⅝	1·02	2·04	3·06	4·08	5·1	6·12	7·14	8·16	9·18	10·2
¾	1·47	2·94	4·41	5·88	7·35	8·82	10·29	11·76	13·23	14·7
⅞	·2	4·	6·	8·	10·	12·	14·	16·	18·	20·
1	2·61	5·22	7·83	10·44	13·05	15·66	18·27	20·88	23·49	26·1
1⅛	3·31	6·62	9·93	13·24	16·55	19·86	23·17	26·48	29·79	33·1
1¼	4·09	8·18	12·27	16·36	20·45	24·54	28·63	32·72	36·81	40·9
1⅜	4·94	9·88	14·82	19·76	24·7	29·64	34·58	39·52	44·46	49·4
1½	5·89	11·78	17·67	23·56	29·45	35·34	41·23	47·12	53·01	58·9
1⅝	6·91	13·82	20·73	27·64	34·55	41·46	48·37	55·28	62·19	69.1
1¾	8·01	16·02	24·03	32·04	40·05	48·06	56·07	64·08	72·09	80·1
1⅞	9·2	18·4	27·6	36·8	46·	55·2	64·4	73·6	82·8	92·
2	10·47	20·94	31·41	41·88	52·35	62·82	73·29	83·76	94·23	104·7
2⅛	11·82	23·64	35·46	47·28	59·1	70·92	82·74	94·56	106·38	118·2
2¼	13·25	26·5	39·75	53·	66·25	79·5	92·75	106·	119·25	132·5
2⅜	14·76	29·52	44·28	59·04	73·8	88·56	103·32	118·08	132·84	147·6
2½	16·36	32·72	49·08	65·44	81·8	98·16	114·52	130·88	147·24	163·6
2⅝	18·03	36·06	54·09	72·12	90·15	108·18	126·21	144·24	162·27	180·3
2¾	19·79	39·58	59·37	79·16	98·95	118·74	138·53	158·32	178·11	197·9
2⅞	21·63	43·26	64·89	86·52	108·15	129·78	151·41	173·04	194·67	216·3
3	23·56	47·12	70·68	94·24	117·8	141·36	164·92	188·48	212·04	235·6
3⅛	25·56	51·12	76·68	102·24	127·8	153·36	178·92	204·48	230·04	255·6
3¼	27·65	55·3	82·95	110·6	138·25	165·9	193·55	221·2	248·85	
3⅜	29·82	59·64	89·46	119·28	149·1	178·92	208·74	238·56	268·38	
3½	32·07	64·14	96·21	128·28	160·35	192·42	224·49	256·56	288·63	
3⅝	34·4	68·8	103·2	137·6	172·	206·4	240·8	275·2	309·6	
3¾	36·81	73·62	110·43	147·24	184·05	220·86	257·67	294·48	331·29	
3⅞	39·31	78·62	117·93	157·24	196·55	235·86	275·17	314·48	353·79	
4	41·88	83·76	125·64	167·52	209·4	251·28	293·16	335·04	376·92	
4⅛	44·54	89·08	133·62	178·16	222·7	267·24	311·78	356·32	400·86	
4¼	47·28	94·56	141·84	189·12	236·4	283·68	330·96	378·24	425·52	
4⅜	50·11	100·22	150·33	200·44	250·55	300·66	350·77	400·88	450·99	
4½	53·01	106·02	159·03	212·04	265·05	318·06	371·07	424·08	477·09	
4⅝	56·	112·	168·	224·	280·	336·	392·	448·	504·	
4¾	59·06	118·12	177·18	236·24	295·3	354·36	413·42	472·48	531·54	
4⅞	62·21	124·42	186·63	248·84	311·05	373·26	435·47	497·68	559·89	
5	65·45	130·9	196·35	261·8	327·25	392·7	458·15	523·6	589·05	

TABLE 13.

Weight of one foot of Hammered Flat Iron ⅝ inch thick.

Width.	2½ in.	2¾.	3.	3¼.	3½.	3¾.	4.	4¼.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	5·25	5·77	6·3	6·82	7·35	7·87	8·4	8·92

Width.	4½.	4¾.	5.	5¼.	5½.	5¾.	6.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	9·45	9·98	10·5	11·03	11·55	12·08	12·6

¾ inch thick.

Width.	2½.	2¾.	3.	3¼.	3½.	3¾.	4.	4¼.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	6·3	6·93	7·56	8·19	8·82	9·45	10·08	10·71

Width.	4½.	4¾.	5.	5¼.	5½.	5¾.	6.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	11·34	11·97	12·6	13·23	13·86	14·49	15·12

⅞ inch thick.

Width.	2½ in.	2¾.	3.	3¼.	3½.	3¾.	4.	4¼.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	7·35	8·08	8·82	9·56	10·29	11·02	11·76	12·5

Width.	4½.	4¾.	5.	5¼.	5½.	5¾.	6.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	13·23	13·97	14·7	15·44	16·17	16·91	17·64

1 *inch thick.*

Width.	2½ in.	2¾.	3.	3¼.	3½.	3¾.	4.	4¼.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	8·4	9·24	10·08	10·92	11·76	12·6	13·44	14·28

Width.	4½.	4¾.	5.	5¼.	5½.	5¾.	6.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	15·12	15·96	16·8	17·64	18·48	19·32	20·16

TABLE 14.

Weight of a Superficial foot of Cast Iron from ¼ to 2 inches thick.

Thickness.	¼.	⅜.	½.	⅝.	¾.	⅞.	1.	1⅛.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight,............................	9·37	14·06	18·75	23·43	28·12	32·81	37·5	42·18

Thickness.	1¼.	1⅜.	1½.	1⅝.	1¾.	1⅞.	2.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight, ...	46·87	51·56	56·25	60·93	65·62	70·31	75·

TABLE 15.

Weight of Cast Iron Pipes, 12 inches long, from ¼ to 1¼ inch thick.

Diam. of Bore.	inch ¼.	inch ⅜.	inch ½.	inch ⅝.	inch ¾.	inch ⅞.	inch 1.	inch 1⅛.	inch 1¼.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3·06	5·06	7·36	9·97	12·89	16·11	19·63		
1¼	3·68	5·98	8·59	11·51	14·73	18·25	22·09		
1½	4·29	6·9	9·82	13·04	16·56	20·4	24·54	28·99	33·74
1¾	4·91	7·83	11·05	14·57	18·41	22·55	27·	31·75	36·76
2	5·53	8·75	12·27	16·11	20·25	24·7	29·45	34·46	39·89
2¼	6·14	9·66	13·5	17·64	22·09	26·84	31·85	37·28	42·95
2½	6·74	10·58	14·72	[illegible]	23·92	28·93	34·36	40·03	46·02
2¾	7·36	11·5	15·95	20·7	25·71	31·14	36·81	42·8	49·08
3	7·98	12·43	17·18	22·19	27·62	33·29	39·28	45·56	52·16
3¼	8·59	13·34	18·35	23·78	29·45	35·44	41·72	48·32	55·22
3½	9·2	14·21	19·64	25·31	31·3	37·58	44·18	51·08	58·29
3¾	9·76	15·19	20·86	26·85	33·13	39·73	46·63	53·84	61·36
4	10·44	16·11	22·1	28·38	34·98	41·88	49·08	56·61	64·43
4¼	11·1	17·08	23·37	29·97	36·87	44·08	51·6	59·42	67·55
4½	11·66	17·94	24·54	31·44	38·65	46·17	53·99	62·12	70·56
4¾	12·27	18·87	25·77	32·98	40·5	48·32	56·45	64·89	73·63
5	12·88	19·78	26·99	34·51	42·33	50·46	58·9	67·64	76·69
5¼	13·5	20·71	28·23	36·05	44·18	52·62	61·36	70·41	79·77
5½	14·11	21·63	29·45	37·58	46·02	54·76	63·81	73·17	82·84
5¾	14·73	22·55	30·68	39·12	47·86	56·91	66·27	75·94	85·91
6	15·34	23·47	31·91	40·65	49·7	59·06	68·73	78·7	88·75
6¼	15·95	24·39	33·13	42·18	51·54	61·21	71·18	81·23	92·04
6½	16·57	25·31	34·36	43·72	53·39	63·36	73·41	84·22	95·1
6¾	17·18	26·23	35·59	45·26	55·23	65·28	76·09	86·97	98·18

TABLE 16.

Weight of Cast Iron Pipes, 12 *inches long, from* ¼ *to* 1¼ *inch thick.*

Diameter of Bore.	inch ¼.	inch ⅜.	inch ½.	inch ⅝.	inch ¾.	inch ⅞.	inch 1.	inch 1⅛.	inch 1¼.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
7	17·79	27·15	36·82	46·79	56·84	67·65	78·53	89·74	101·24
7¼	18·41	28·08	38·05	48·1	58·91	69·79	81·	92·5	104·31
7½	19·03	29·	39·05	49·86	60·71	71·95	83·45	95·26	107·38
7¾	19·64	29·69	40·5	51·38	62·59	74·09	85·9	98·02	110·45
8	20·02	30·83	41·71	52·92	64·42	76·23	88·35	100·78	113·51
8¼	20·86	31·74	42·95	54·45	66·26	78·38	90·81	103·54	116·58
8½	21·69	32·9	44·4	56·21	68·33	80·76	93·49	106·53	119·87
8¾	22·09	33·59	45·4	57·52	69·95	82·68	95·72	109·06	122·72
9	22·71	34·52	46·64	59·07	71·8	84·84	98·18	111·84	125·8
9¼	23·31	35·43	47·86	60·59	73·63	86·97	100·63	114·59	128·85
9½	23·93	36·36	49·09	62·13	75·47	89·13	103·09	117·35	131·95
9¾	24·55	37·28	50·32	63·66	77·32	91·28	105·54	120·12	134·99
10	25·16	38·2	51·54	65·2	79·16	93·42	108·	122·87	138·06
10¼	25·77	39·11	52·77	66·73	80·99	95·57	110·44	125·63	141·12
10½	26·38	40·04	54·	68·26	82·84	97·71	112·9	128·39	144·19
10¾	27·	40·96	55·22	69·8	84·67	99·86	115·35	131·15	147·26
11	27·62	41·88	56·46	71·33	86·52	102·01	117·81	133·92	150·33
11¼	28·22	42·8	57·67	72·86	88·35	104·15	120·26	136·67	153·4
11½	28·84	43·71	58·9	74·39	90 19	106·3	122·71	139·44	156·44
11¾	29·45	44·64	60·13	75·93	92·04	108·45	125·18	142·18	159·54
12	30·06	45·55	61·35	77·46	93·6	110·6	127·6	144·96	162·6

TABLE 17.

Weight of Cast Iron Plates from one to nine Superficial inches in area, and from ⅛ of an inch to one inch in thickness.

Supfi. feet inches.	⅛ thick. lbs.	¼ thick. lbs.	⅜ thick. lbs.	½ thick. lbs.	⅝ thick. lbs.	¾ thick. lbs.	⅞ thick. lbs.	1 thick. lbs.
1	·032552	·065104	·097656	·130208	·16276	·195312	·227864	·260416
2	·065104	·130208	·195312	·260416	·32552	·390624	·455728	·520832
3	·097656	·195312	·292968	·390624	·48828	·585936	·683592	·781248
4	·130208	·260416	·390624	·520832	·65104	·781248	·911456	1·041664
5	·16276	·32552	·48828	·65104	·8138	·97656	1·13932	1·30208
6	·195312	·390624	·585936	·781248	·97656	1·171872	1·367184	1·562496
7	·227864	·455728	·683592	·911456	1·13932	1·367184	1·595048	1·822912
8	·260416	·520832	·781248	1·041664	1·30208	1·562496	1·822912	2·083328
9	·292968	·585936	878904	1·171872	1·46484	1·757808	2·050776	2·343744

This Table shews the weight of any number of superficial inches of Cast Iron between one and nine, and from one eighth of an inch to one inch in thickness.

The weight for tens, hundreds, thousands, &c. may be very readily obtained, by bringing forward as many of the Decimals to the whole numbers as the number of superficial inches is removed from the units place; and should the thickness of the metal be greater than one inch, its weight may be found, by adding together any two of the columns, which are equal to the given thickness:—or by multiplying the column containing half the thickness by 2.

EXAMPLE 1st.

What is the weight of 1728 superficial inches of Cast Iron, one inch in thickness.

Super. inches.		lbs.
1000	=	.... 260·416
700	=	.... 182·2912
20	=	.... 5·20832
8	=	.... 2·08332
		Answer,...... 449·99884

EXAMPLE 2nd.

Required the weight of a Cast Iron Girder, 30 feet in length, 22 inches in depth, and 1½ inch in thickness. (Taken from the ¾ inch column.)

30 Feet.
12
———
360 inches
22 depth
———
720
720
———
7920 area in inches

Super. inches.		lbs.
7000	=	1367·184
900	=	175·7808
20	=	3·90624
		1546·87104
		2
		Answer,...... 3093·74208

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G. H. Huttmann, Bengal Military Orphan Press.